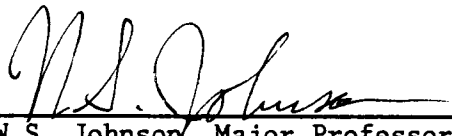
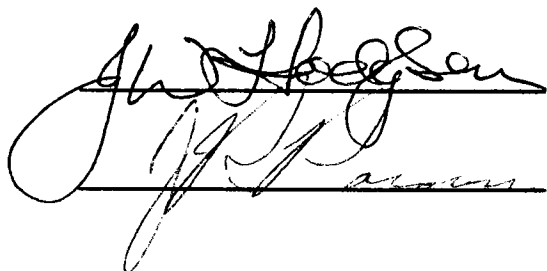


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PERFORMANCE EVALUATION OF A
DUAL-SPEED HEAT PUMP

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

John Randall Carr

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ABSTRACT

An air-to-air heat pump with a two-speed compressor was installed in a single-family residence near Knoxville, Tennessee, and was operated in a weekly alternating schedule of dual and single-speed modes over a full heating and cooling season to permit performance evaluation of the two modes. The residence and the heat pump were extensively instrumented in order to monitor performance of the unit along with its degradation from steady-state performance for both modes of operation.

For the heating season, the heat pump had a performance factor of 2.17 in the dual-speed mode and a performance factor of 2.11 in the single-speed mode. For the cooling season, the heat pump had performance factors of 2.27 and 2.09 for the dual and single-speed modes respectively. Annual performance factors were 2.20 and 2.10 for the dual and single-speed modes respectively.

Also, an annual performance factor (APF) model created by Oak Ridge National Laboratory for residential air-source heat pumps was used to generate computer simulations of the field performance. Heating season performance factor (HSPF) values were 2.00 for the single-speed mode and 2.05-2.13, depending upon the switch-over temperature used, for the dual-speed mode. The cooling season performance factor (CSPF) values were 1.85 for the single-speed mode and 2.23 for the dual-speed mode. The switch-over from low to high

speed compressor for the dual-speed mode during the cooling season was determined by whether or not the system could meet the cooling load or not. If the heat pump system could not meet this cooling load in low speed compressor it would shut off and come back on in high speed compressor operation. Annual performance factor values were 1.94 for the single-speed mode and 2.12-2.17, depending upon the switch-over temperature used for heating, for the dual-speed mode.

Based on the findings of the field analysis, it is believed that the switch-over control method from low to high speed compressor operation during the heating season that was used on this unit was not very effective at offering the potential enhancements of the dual-speed mode over the single-speed mode. It is recommended that this area be addressed in future studies. Also, the fact that the dual-speed mode always had a higher sensible heat ratio than the single-speed mode during the cooling season should be investigated in future studies in regard to its effect on the comfort level of the indoor air space.

TABLE OF CONTENTS

CHAPTER	PAGE
I. INTRODUCTION	1
Discussion of Operation	1
Historical Development of the Heat Pump	3
Developments in Dual-Speed Compressors	5
II. TEST SITE AND EQUIPMENT	7
Test Facilities	7
Test Equipment	7
Data Acquisition	10
III. HEATING SEASON PERFORMANCE	13
Introduction	13
Steady-State Performance Base	15
Test Results	19
Comparison of Test Results to Steady-State Performance	26
Effects of Strip Heat Upon Performance	26
Effects of Defrosting Upon Performance	30
Effects of Transient Stage Upon Performance	31
Effects of Off-Cycle Crankcase Heater Energy Consumption Upon Performance	36
Comparison of Demand and Timer Defrost System	37
IV. COOLING SEASON PERFORMANCE	40
Introduction	40
Steady-State Performance Base	42

CHAPTER	PAGE
Test Results	46
Comparison of Test Results to Steady-State Performance .	50
Effects of Transient Stage Upon Performance	54
Effects of Off-Cycle Crankcase Heater Energy Consumption Upon Performance	60
V. COMPUTER MODELLING	61
Introduction	61
Results	67
Comparison of the APF/Loads Model Results to the Field Results	80
VI. CONCLUSIONS AND RECOMMENDATIONS	93
Heating Season Conclusions	93
Cooling Season Conclusions	94
Computer Model Analyses Conclusions	94
Recommendations	96
LIST OF REFERENCES	97
APPENDIXES	99
APPENDIX A. FIELD RESULTS	100
Single-Speed Mode Heating Bin Data Results	101
Dual-Speed Mode Heating Bin Data Results	102
Dual-Speed Mode (Low Hours Only) Heating Bin Data Results	103
Dual-Speed Mode (High Hours Only) Heating Bin Data Results	104

CHAPTER	PAGE
Single-Speed Mode Cooling Bin Data Results	105
Dual-Speed Mode Cooling Bin Data Results	106
Single and Dual-Speed Mode's Heating Analysis Computer Program	107
Dual-Speed Mode's (Low Hours Only) Heating Analysis Computer Program	112
Dual-Speed Mode's (High Hours Only) Heating Analysis Computer Program	117
Heating Bin Value Descriptions	122
Single-Speed Mode's Cooling Analysis Computer Program . .	126
Dual-Speed Mode's Cooling Analysis Computer Program . . .	130
Cooling Bin Value Descriptions	134
APPENDIX B. APF/LOADS MODEL RESULTS	137
Single-Speed Mode HVAC System Data File	138
Dual-Speed Mode HVAC System Data File	139
Single-Speed Mode Load Data File	140
Dual-Speed Mode Load Data File	144
Heating Season Load Manipulation Computer Program	148
Cooling Season Load Manipulation Computer Program for the Single-Speed Mode	151
Cooling Season Load Manipulation Computer Program for the Dual-Speed Mode	154
Single-Speed Mode BLOCK Subroutine Calender Information .	157
Dual-Speed Mode BLOCK Subroutine Calender Information . .	157

CHAPTER	PAGE
Dual-Speed Mode SSTATE Subroutine Sample Listing	158
Single-Speed Mode HVAC/Loads Data File Results	160
Dual-Speed Mode HVAC/Loads Data File Results (SOT=47°F) .	167
Dual-Speed Mode HVAC/Loads Data File Results (SOT=42°F) .	176
Dual-Speed Mode HVAC/Loads Data File Results (SOT=37°F) .	185
Dual-Speed Mode HVAC/Loads Data File Results (SOT=32°F) .	194
Single-Speed Mode HVAC/Loads Data File Results for Load Conditions Identical to Dual-Speed Loads	203
APPENDIX C	210
Uncertainty Analysis	211
VITA	213

LIST OF TABLES

TABLE		PAGE
2.1	Cooling Capacity in Btu/hr for Low Speed Compressor	
	Operation	8
2.2	Cooling Capacity in Btu/hr for High Speed Compressor	
	Operation	8
2.3	Heating Capacity in Btu/hr for Low Speed Compressor	
	Operation	9
2.4	Heating Capacity in Btu/hr for High Speed Compressor	
	Operation	9
2.5	TECH House III Data Variables and Descriptions	11
3.1	Heating Season Monthly Data Sets for Single-Speed Mode . .	14
3.2	Heating Season Monthly Data Sets for Dual-Speed Mode . . .	14
3.3	Compressor Motor Input in Watts for Low Speed Compressor	
	Operation	16
3.4	Compressor Motor Input in Watts for High Speed Compressor	
	Operation	16
3.5	Low Speed Compressor Steady-State Data	16
3.6	High Speed Compressor Steady-State Data	17
3.7	Energy Input Breakdown Over the Heating Season for the	
	Single-Speed Mode	23
3.8	Energy Input Breakdown Over the Heating Season for the	
	Dual-Speed Mode	23
3.9	Degradation Factors for the Heating Season	25

TABLE	PAGE
3.10 Comparison of % Time in Defrost vs. Bin Temperature . . .	38
3.11 Demand Defrost System Input Energy Savings for the Single-Speed Mode	38
3.12 Demand Defrost System Input Energy Savings for the Dual-Speed Mode	39
4.1 Cooling Season Monthly Data Sets for Single-Speed Mode . .	41
4.2 Cooling Season Monthly Data Sets for Dual-Speed Mode . . .	41
4.3 Compressor Motor Input in Watts for Low Speed Compressor Operation	43
4.4 Compressor Motor Input in Watts for High Speed Compressor Operation	43
4.5 Low Speed Compressor Steady-State Data	44
4.6 High Speed Compressor Steady-State Data	44
4.7 Energy Input Breakdown Over the Cooling Season for the Single-Speed Mode	49
4.8 Energy Input Breakdown Over the Cooling Season for the Dual-Speed Mode	49
4.9 Degradation Factors for the Cooling Season	50
5.1 Program Option Switch Descriptions	63
5.2 Performance Values Obtained from the APF/Loads Model . . .	70
5.3 Heating Loss Mechanism Energy Inputs and Percentage of Total Summary	71
5.4 Types of Hours that the Dual-Speed Mode Experienced During the Heating Season	72

TABLE	PAGE
5.5 Cooling Cycling Loss Energy Input and Percentage of Total Summary	74
5.6 Performance Values Comparison Summary for the Single and Dual-Speed Modes	81
5.7 Comparison of the APF/Loads Model and Field Heating Loss Mechanism Inputs and Percentage of Total Summary for the Single and Dual-Speed Modes	85
5.8 Comparison of the APF/Loads Model and Field Defrost Data for the Single and Dual-Speed Modes	86
5.9 Comparison of the APF/Loads Model and Field Cooling Cycling Loss Energy Input and Percentage of Total Summary for the Single and Dual-Speed Modes	89
5.10 Comparison of the APF/Loads Model and Field Heating Parameters with Adjusted " C_D " Values	91
5.11 Comparison of the APF/Loads Model and Field Cooling Parameters with Adjusted " C_D " Values	92
C.1 Overall Results of Uncertainty Analysis	212

LIST OF FIGURES

FIGURE	PAGE
3.1	Manufacturer's Heating COP vs. Ambient Temperature for Low and High Speed Compressor Operation 18
3.2	Comparison of Overall COP's (with Crankcase) for Single and Dual-Speed Modes 20
3.3	Comparison of Percent Time Transient for Single and Dual-Speed Modes 21
3.4	Comparison of Different Heating COP's for the Single-Speed Mode 27
3.5	Comparison of Different Heating COP's for the Dual-Speed Mode, High Speed Compressor Hours 28
3.6	Comparison of Different Heating COP's for the Dual-Speed Mode, Low Speed Compressor Hours 29
3.7	Comparison of Transient and Normal COP's without Crankcase for the Single-Speed Mode 32
3.8	Comparison of Transient and Normal COP's without Crankcase for the Dual-Speed Mode 33
3.9	Comparison of Normal COP's without Crankcase and Strip Heat for the Single and Dual-Speed Modes 34
3.10	Comparison of Transient COP's (without Crankcase) for the Single and Dual-Speed Modes 35
4.1	Manufacturer's Cooling COP vs. Ambient Temperature for Low and High Speed Compressor Operation 45

4.2	Comparison of Overall COP's (with Crankcase) for Single and Dual-Speed Modes	47
4.3	Comparison of Sensible Heat Ratios for Single and Dual-Speed Modes	48
4.4	Comparison of Different Cooling COP's for the Single-Speed Mode	51
4.5	Comparison of Different Cooling COP's for the Dual-Speed Mode	52
4.6	Comparison of Transient and Normal COP's without Crankcase for the Single-Speed Mode	55
4.7	Comparison of Transient and Normal COP's without Crankcase for the Dual-Speed Mode	56
4.8	Comparison of % Time Transient for the Single and Dual-Speed Modes	57
4.9	Comparison of Normal COP's (without Crankcase) for the Single and Dual-Speed Modes	58
4.10	Comparison of Transient COP's (without Crankcase) for the Single and Dual-Speed Modes	59
5.1	Field Measured Cooling Capacities for Low and High Speed Compressor Operation	65
5.2	Comparison of Predicted Overall Heating APF/Loads Model COP's for the Single and Dual-Speed Modes	73

5.3	Comparison of Predicted Overall Cooling APF/Loads Model	
	COP's for the Single and Dual-Speed Modes	76
5.4	Comparison of Predicted Overall Heating APF/Loads Model	
	COP's for the Single and Dual-Speed Modes Under the Same	
	Load Conditions	78
5.5	Comparison of Predicted Overall Cooling APF/Loads Model	
	COP's for the Single and Dual-Speed Modes Under the Same	
	Load Conditions	79
5.6	Comparison of Overall APF/Loads Model and Field Heating	
	COP's for the Single-Speed Mode	82
5.7	Comparison of Overall APF/Loads Model and Field Heating	
	COP's for the Dual-Speed Mode	84
5.8	Comparison of Overall APF/Loads Model and Field Cooling	
	COP's for the Single-Speed Mode	87
5.9	Comparison of Overall APF/Loads Model and Field Cooling	
	COP's for the Dual-Speed Mode	88

LIST OF ABBREVIATIONS

HSPF	Heating Season Performance Factor
CSPF	Cooling Season Performance Factor
APF	Annual Performance Factor
COP	Coefficient of Performance
TECH	Tennessee Energy Conservation in Housing
DAS	Data Acquisition System
RTD	Resistance Temperature Device
I ² r	Strip Heat
COPN	Coefficient of Performance Based on Normal Field Data
COPSS	Coefficient of Performance Based on Steady-State Data
BO	Based on
N	Normal Field Data Reference
SS	Manufacturer's Steady-State Data Reference
wo	Without
w/o	Without
ORNL	Oak Ridge National Laboratory
SOT	Switch-Over Temperature
NBS	National Bureau of Standards
DOE	Department of Energy
HP	Heat Pump

CHAPTER I

INTRODUCTION

1.1 Discussion of Operation

The performance of an air-to-air heat pump, when operating under field conditions, is degraded from that measured at steady-state and reported by equipment manufacturers. During the heating season, this degradation in performance is due to three factors: frosting, defrosting, and cycling. During the cooling season, cycling is the primary cause of performance degradation.

A heat pump is usually sized to meet its maximum cooling load requirements, however, part-load operation can substantially reduce the system's efficiency due to frequent cycling. Therefore, a two-speed compressor which operates in low speed for small loads and high speed for larger loads offers a potentially higher seasonal performance.

Frost forms on the outside coil during the heating process when the coil surface temperature is below freezing and the ambient relative humidity is high. This build-up of frost restricts the flow of air over the coil surface and acts as a thermal resistance to the transfer of heat from the ambient air to the refrigerant. Therefore the heating capacity of the system is reduced.

When the build-up of frost becomes large, the heat pump switches to the defrost mode to melt and drain away the accumulated frost. In this mode, the unit operates as an air conditioner,

taking heat from the conditioned space. To maintain comfort within this space, supplemental electric heaters are energized. As a result, the net heat addition to the indoor air is very small and the performance is greatly reduced.

As previously mentioned, frequent cycling can substantially reduce the heat pump's performance. At the beginning of each cycle for the system, a finite time elapses before the system reaches steady-state performance. During this time, lower heating and cooling performance and capacity are attained. Due to a pressure decrease across the expansion valve of the heat pump system, the refrigerant tends to flow toward the low pressure side during the off-cycle period. When the system starts up again, a lower flow rate of refrigerant is handled by the compressor and a lower inlet condenser temperature is achieved. Thus, there is less heat rejection in the condenser and less heat addition in the evaporator by the refrigerant. As the system continues to run, it corrects this problem. Steady-state operation is attained in two to five minutes.

This report deals with experimental and analytical determination of the field performance of a two-speed heat pump system. A weekly alternating schedule of single and dual-speed modes over a full heating and cooling season was utilized on the installed heat pump. In the single-speed mode the compressor always ran in the high speed mode when the system was on while in the dual-speed mode the compressor ran either in high or low speed

depending on the load conditions. The purpose of this testing was to compare the performance of the two modes of operation.

The house and the heat pump system were exposed to a wide range of operating conditions during the testing. The overall performance and degradations due to cycling and defrosting were quantified and compared for the two modes. An annual performance factor model (1) was used to calculate seasonal performance values and degradations for comparison with the field measured data.

1.2 Historical Development of the Heat Pump

The basic principles of the heat pump were derived from the work in the early 1800's and thesis publication on the Carnot cycle in 1824 by Sadi Carnot, a French army officer. In 1852, William Thomson, later to be known as Lord Kelvin, was the first to propose a practical heat pump, or heat multiplier as he referred to it. In his heat multiplier air was used on an open cycle in which it was first taken from the external atmosphere and was then expanded in a cylinder to a lower temperature and pressure. The air was then passed through an air-to-air heat exchanger where it picked up heat from the external atmosphere. After this it was compressed in a cylinder back to atmospheric pressure and was then passed into the building for heating. Thomson realized that the economical practicality of his heat multiplier would improve as the price of the natural resources currently being used for heating purposes increased. He also envisioned use of the device for cooling instead of heating.

In 1930, Haldene published a paper that described his 1927 installation of a domestic heat pump in Scotland (2). It provided heat for hot water and space heating using outside air as the heat source. The first large-scale heat pump installation occurred in 1930-1931 in the Los Angeles offices of the Southern California Edison Company and was used for heating purposes only (3). The first major heat pump installation in Europe occurred in Zurich in 1938 (2). In it the refrigerant R-12 and a rotary compressor were used with outside river water as the heat source. It was used to heat the Town Hall and had an output of 175 Kw that supplied water at a temperature of 60°C for space heating. Nine other installations followed in Switzerland from 1939-1945, their motivation being to decrease the coal consumption in that country (2). The installation in the Equitable Building in Portland, Oregon of 1948, that was utilized for heating and cooling has received critical acclaim as a pioneering development of the Western Hemisphere (3).

As the developments continued it was realized that a unitary heat pump system factory engineered and assembled was necessary (2,3). In 1952 heat pumps manufactured along these lines were available. By 1963 76,000 units were manufactured (2,3). These were installed in the southern United States where both heating and cooling were required. Reliability problems associated with these units together with decreasing electric rates during the 1960's (which made electrical heating techniques more cost attractive)

caused the demand for heat pumps to level off. Improvements in system reliability along with the energy crisis of the early 1970's led to a resurgence in the demand for heat pumps.

1.3 Developments In Dual-Speed Compressors

As previously mentioned, frequent cycling at part-load operation of a single-speed heat pump system leads to a degradation from steady-state performance during the first two to five minutes of each on-cycle due to the transient behavior of the refrigerant. To reduce the amount of on/off cycling that a heat pump system experiences, various capacity modulation techniques are employed. These techniques include the following: two-speed motors, blocked suction, dual compressors, gas bypass compressors, variable speed motors, geared compressors, and variable displacement compressors (4). In theory, the variable speed motor technique, which is the adjustment of the capacity to match the load is the most effective way to reduce the cycling losses that a single-speed system experiences. Due to the high cost associated with varying the motor speed this technique is currently not economically feasible in residential applications. Considering the economic and operational advantages and disadvantages of each capacity modulation technique, the two-speed motor, or dual-speed compressor was considered to be the most effective at bridging the gap between the single-speed compressor and the variable speed compressor systems for residential applications.

The first dual-speed hermetic compressor was built and tested in 1971 and was later installed in a field application where it continues to operate today (5). In 1973 a 15-ton dual-speed hermetic compressor was installed for a cooling only application (5). In 1975 residential size dual-speed hermetic compressors (5-ton and smaller) went into production for cooling applications (5). The success of these early developments led to the production of a residential dual-speed hermetic compressor in 1978 to be used for both heating and cooling (5).

CHAPTER II

TEST SITE AND EQUIPMENT

2.1 Test Facilities

The test heat pump was installed in TECH House III located on the Tennessee Energy Conservation in Housing (TECH) complex near Knoxville, Tennessee. TECH House III is a 167-m², well-insulated structure with R-19 walls and a R-38 ceiling. Although unoccupied during the testing, it had internal loads simulating occupancy by a family of four. Its design loads were 30,000 Btu/hr during the heating season and 22,000 Btu/hr during the cooling season. A complete description of the complex may be found in References 6 and 7.

2.2 Test Equipment

The heat pump system used for these tests was a state-of-the-art two-speed unit of split system (seperate indoor and outdoor units) design. Tables 2.1 and 2.2 show manufacturer's data for the cooling capacity for low speed and high speed compressor operation. Tables 2.3 and 2.4 show the heating capacity. The compressor of the system was designed for two-speed operation to give staging control to fit varying heating and cooling load requirements. Low speed compressor operation was 1750 rpm while high speed compressor operation was 3500 rpm. The unit was equipped with an air pressure differential defrost control system. A factory

Table 2.1 Cooling Capacity in Btu/hr for Low Speed
Compressor Operation

Entering Indoor Wet Bulb (°F)	Indoor Coil Air Volume (cfm)	Air Temperature Entering Outdoor Coil (°F)			
		75	85	95	105
63	700	22,200	20,800	19,500	18,200
	800	22,800	21,400	20,200	18,900
	900	23,300	22,100	20,800	19,600
67	700	23,800	22,300	20,800	19,300
	800	24,300	22,800	21,200	19,700
	900	24,700	23,100	21,600	20,000
71	700	25,500	24,000	22,400	20,800
	800	26,000	24,400	22,800	21,200
	900	26,400	24,800	23,100	21,400

Table 2.2 Cooling Capacity in Btu/hr for High Speed
Compressor Operation

Entering Indoor Wet Bulb (°F)	Indoor Coil Air Volume (cfm)	Air Temperature Entering Outdoor Coil (°F)			
		85	95	105	115
63	1200	36,800	34,400	32,100	30,300
	1350	37,700	35,200	33,300	31,400
	1500	38,500	36,300	34,200	32,300
67	1200	39,500	36,900	34,400	32,100
	1350	40,200	37,500	35,000	32,600
	1500	40,800	38,000	35,500	33,100
71	1200	42,500	39,800	37,200	34,700
	1350	43,200	40,400	37,700	35,200
	1500	43,700	40,900	38,100	35,500

Table 2.3 Heating Capacity in Btu/hr for Low Speed Compressor Operation

Indoor Coil Air Volume (cfm) 70°F db	Air Temperature Entering Outdoor Coil (°F)			
	65	60	55	50
1200	29,000	27,100	25,300	23,400
1350	29,300	27,400	25,600	23,700
1500	29,600	27,700	25,800	23,900

Table 2.4 Heating Capacity in Btu/hr for High Speed Compressor Operation

Indoor Coil Air Volume (cfm) 70°F db	Air Temperature Entering Outdoor Coil (°F)				
	65	45	25	5	-15
1200	45,200	34,500	24,100	15,200	7800
1350	45,900	35,000	24,500	15,600	8000
1500	46,500	35,500	24,900	15,900	8200

installed air pressure switch activated by the pressure difference across the outdoor coil, due to frost accumulation, automatically initiated the defrost cycle. The defrost cycle was terminated by a temperature sensing element which sensed the refrigerant temperature leaving the outdoor coil. The compressor was equipped with an off-cycle crankcase heater.

2.3 Data Acquisition

A data acquisition system (DAS) located in TECH House II monitored data used for the performance analysis of the heat pump. Hourly integrated totals of space heating, latent cooling and sensible heat flows were recorded along with individual component power consumptions, outdoor and indoor ambient conditions. A complete listing of recorded data appears in Table 2.5.

Space heating and sensible cooling loads delivered were measured by means of an air-side heat flow metering system consisting of two averaging resistance temperature devices (RTD's) and a vane anemometer located in the return air duct. Electrical energy consumption values were measured by conventional watt-hour meters fitted with optical disc revolution counters. A more detailed description of the instrumentation is given in References 8 and 9.

Some problems were encountered with the magnetic tape storage of data during certain periods of time for the heating and cooling season. However, most of the missing data was available on the hard copy back-up storage system.

In order to be able to quantify the energy use for transient, normal, and defrost operation it was necessary to store data in different sets during each heat pump operating cycle. The DAS interface was set up to store data in one set of channels during the

Table 2.5 TECH House III Data Variables and Descriptions

Data Point	Variable	Description
1	15	Outdoor Relative Humidity (%)
2	44	Compressor Total Power (W-hr)
3	48	Total House Power (W-hr)
4	49	Hot Water Heater (W-hr)
5	50	Indoor Fan Transient (W-hr)
6	51	Indoor Fan Normal (W-hr)
7	52	Indoor Fan Defrost (W-hr)
8	53	Outdoor Fan Transient (W-hr)
9	54	Outdoor Fan Normal (W-hr)
10	55	Outdoor Fan Defrost (W-hr)
11	56	Compressor Transient (W-hr)
12	57	Compressor Normal (W-hr)
13	58	Compressor Defrost (W-hr)
14	59	Strip Heat Transient (W-hr)
15	60	Strip Heat Normal (W-hr)
16	61	Strip Heat Defrost (W-hr)
17	62	Crankcase Heater (W-hr)
18	63	Number of Times Heat Pump Comes On
19	64	Number of Defrost Cycles Called For
20	65	Condensate Collected (kg)
21	68	Number of Auxiliary Heat Cycles
22	70	Compressor High Speed Runtime (sec)
23	71	Compressor Low Speed Runtime (sec)
24	72	Time in Defrost Cycle (sec)
25	73	Number of High Speed Cycles
26	74	Number of Low Speed Cycles
27	75	Indoor Fan Runtime (sec)
28	76	Transient Heat Flow to Airstream (W-hr)
29	77	Normal Heat Flow to Airstream (W-hr)
30	78	Defrost Heat Flow to Airstream (W-hr)
31	79	Desuperheater Heat Flow (W-hr)
32	80	Airstream Sensible Heat Flow (W-hr)
33	131	Outside Dry Bulb Temperature (°C)
34	165	Fan Coil Inlet Temperature (°C)
35	166	Fan Coil Outlet Temperature (°C)
36	169	Inside Dry Bulb Temperature (°C)
37	399	Heating Load (W-hr)
38	400	Cooling Load (W-hr)
39	402	Latent Cooling Load (W-hr)
40	417	Indoor Relative Humidity (%)

first four minutes of each cycle (start-up transient), a second set during defrost and return from defrost recovery periods (defrost), and a third set at all other times during the cycle (normal).

CHAPTER III

HEATING SEASON PERFORMANCE

3.1 Introduction

The results of tests during five winter months over the 1984-85 heating season and analyses of the test data for both modes of operation are described in this section. Table 3.1 lists the single-speed mode data sets and the number of hours included in each upon which the test results and analyses are based. Table 3.2 lists the dual-speed mode data sets. A detailed tabulation of the compressed raw data set and test results is given on pages 101-104 in Appendix A, Sections A.1-A.4, for 5°C-wide bins. The sections are for single-speed mode and dual-speed mode including combined low and high speed performance, low speed performance only and high speed performance only, respectively, and are for the entire heating season. The following sections will discuss steady-state performance, effects of transient and defrost operation on performance, and a comparison of the demand defrost used on this system and the timer defrost used on the heat pump system analyzed in Reference 10 is given.

In the dual-speed mode, the need for high speed compressor operation was determined by the dry bulb temperature of the air entering the outdoor coil. An outdoor thermostat set at 42°F (with a +6 F° to -6 F° dead band) controlled the compressor operating speed. If the air temperature was below this setpoint the system

Table 3.1 Heating Season Monthly Data Sets for
Single-Speed Mode

Month	Days Included in data set	Data* Hours
December 1984	December 4-9,24-25	190
January 1985	January 8-13,22-29	336
February 1985	February 5-10,20-24	260
March 1985	March 5-10,26-31	288
April 1985	April 10-14	120

* Total hours minus those hours with missing or suspect data

Table 3.2 Heating Season Monthly Data Sets for
Dual-Speed Mode

Month	Days included in data set	Data* Hours
December 1984	December 11-16,27-30	240
January 1985	January 15-20, 31	158
February 1985	February 1-3,15-18,26-28	240
March 1985	March 1-3,12-24	384
April 1985	April 2-8	168

* Total hours minus those hours with missing or suspect data

would start-up in high speed, or, if already running in low speed, it would continue to run until it cycled off after which it would start up in the high speed mode when next called upon by the indoor thermostat. Because of the thermostat dead band, this switch-over could occur over a temperature range of 36°F to 48°F.

3.2 Steady-State Performance Base

At the present the only source available for determining the steady-state performance of the test heat pump was the manufacturer's ratings. Shown in Tables 2.3 and 2.4 of the previous chapter on page 9 are the heating capacities for low and high speed compressor operation, respectively, as given by the manufacturer. Tables 3.3 and 3.4 show the given compressor motor inputs for low and high speed compressor operation. Determining the heating capacities and compressor inputs by linearly extrapolating the manufacturer's data to the system's actual indoor coil air volume of 1050-1100 cubic feet per minute (cfm) and using field data to approximate the indoor and outdoor fan consumptions at the different ambient temperatures, the steady-state performance values were calculated. Tables 3.5 and 3.6 show the low and high speed compressor steady-state data along with the calculated COP's for the different temperatures. Figure 3.1 shows the various data points for low speed and high speed compressor operation along with the best fit straight line calculated for both.

Table 3.3 Compressor Motor Input in Watts for Low Speed
Compressor Operation

Indoor Coil Air Volume (cfm) 70°F db	Air Temperature Entering Outdoor Coil (°F)			
	65	60	55	50
1200	1460	1420	1380	1340
1350	1440	1400	1370	1330
1500	1420	1390	1350	1320

Table 3.4 Compressor Motor Input in Watts for High Speed
Compressor Operation

Indoor Coil Air Volume (cfm) 70°F db	Air Temperature Entering Outdoor Coil (°F)				
	65	45	25	5	-15
1200	3360	2830	2310	1925	1475
1350	3310	2810	2300	1910	1465
1500	3270	2800	2290	1895	1455

Table 3.5 Low Speed Compressor Steady-State Data

Ambient Air Temperature (°C)	Total Heating Capacity (watts)	Compressor Input (watts)	Indoor Fan Input (watts)	Outdoor Fan Input (watts)	COP
18.33	8409	1480	504	322	3.65
15.56	7852	1440	505	324	3.46
12.78	7354	1400	506	326	3.29
10.00	6798	1345	507	328	3.12

Table 3.6 High Speed Compressor Steady-State Data

Ambient Air Temperature (°C)	Total Heating Capacity (watts)	Compressor Input (watts)	Indoor Fan Input (watts)	Outdoor Fan Input (watts)	COP
18.33	13067	3400	504	322	3.09
7.22	9962	2840	505	329	2.71
-15.00	4336	1935	505	340	1.56
-26.10	2227	1485	505	344	.95

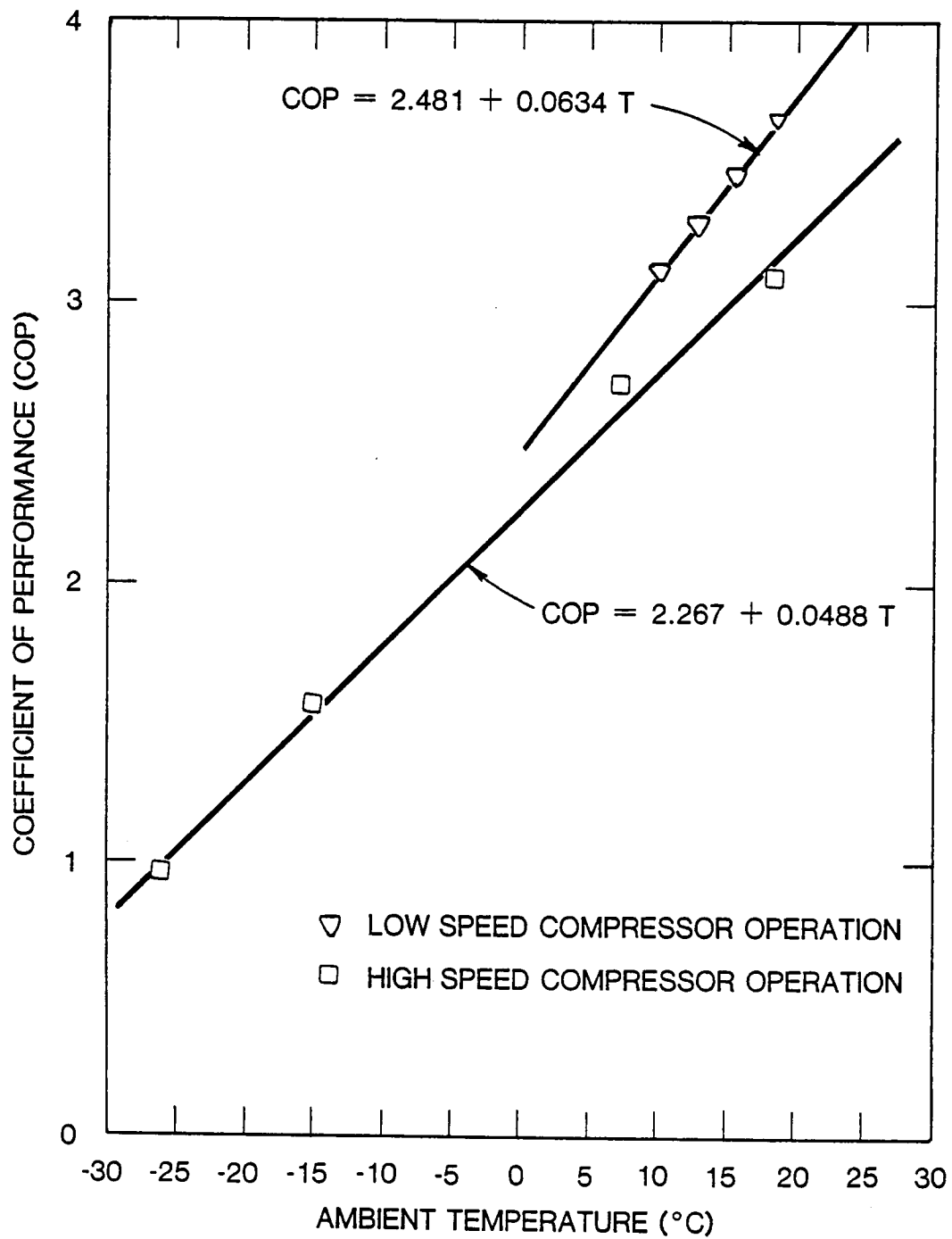


Figure 3.1 Manufacturer's Heating COP vs. Ambient Temperature for Low and High Speed Compressor Operation

3.3 Test Results

In Appendix A, Section A.7 on pages 107-111 gives a listing of the computer program used to generate Sections A.1 and A.2 on pages 101-102. Bin value descriptions for the heating season are given in Appendix A, Section A.10 on pages 122-125. Figure 3.2 shows overall COP vs. bin temperature for both modes of operation. From this and the raw data sets given in Sections A.1 and A.2 the following conclusions can be made:

1. The dual-speed mode generally has higher performance values for temperatures above -10°C . From Figure 3.3 which shows % time transient vs. bin temperature, the dual-speed mode operates less in the transient stage than the single-speed mode. Hence, less cycling in dual-speed and higher performance. Note that the data point shown in the $-20/15^{\circ}\text{C}$ temperature bin for the dual-speed mode is not connected to the other dual-speed mode data points due to the fact that there is no transient operating time in the $-15/-10^{\circ}\text{C}$ temperature bin. This convention will be used throughout this report when dealing with missing data points.

2. In the 0 to 5°C temperature bin the overall COP of the dual-speed mode is slightly less than the overall COP of the single-speed mode. This may be due partly because the average temperature is lower and the average relative humidity is higher in this particular bin for the dual-speed mode and thus this mode has a higher % defrost time, 1.803% compared with 0.685% for the single-speed mode.

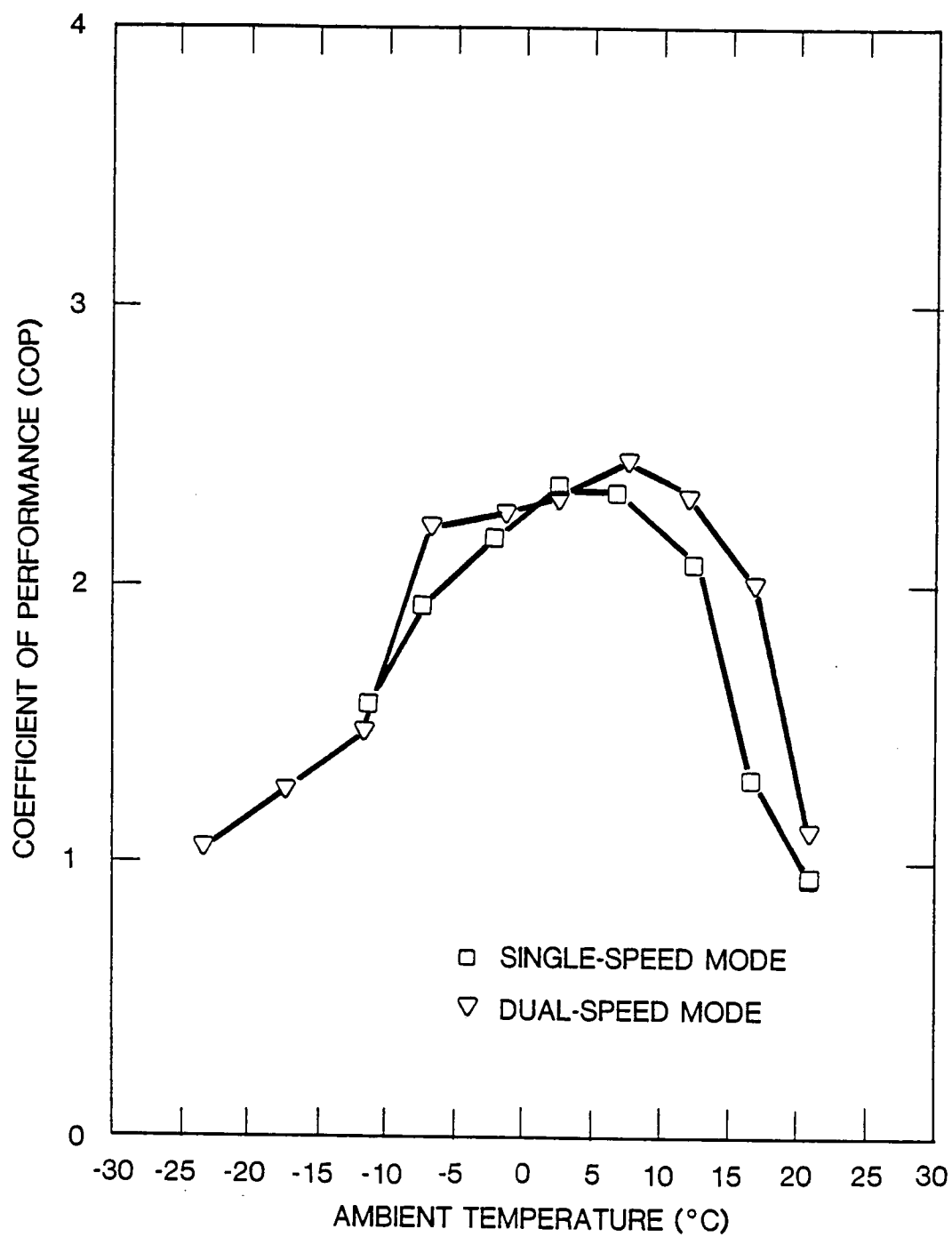


Figure 3.2 Comparison of Overall COP's (with Crankcase) for Single and Dual-Speed Modes

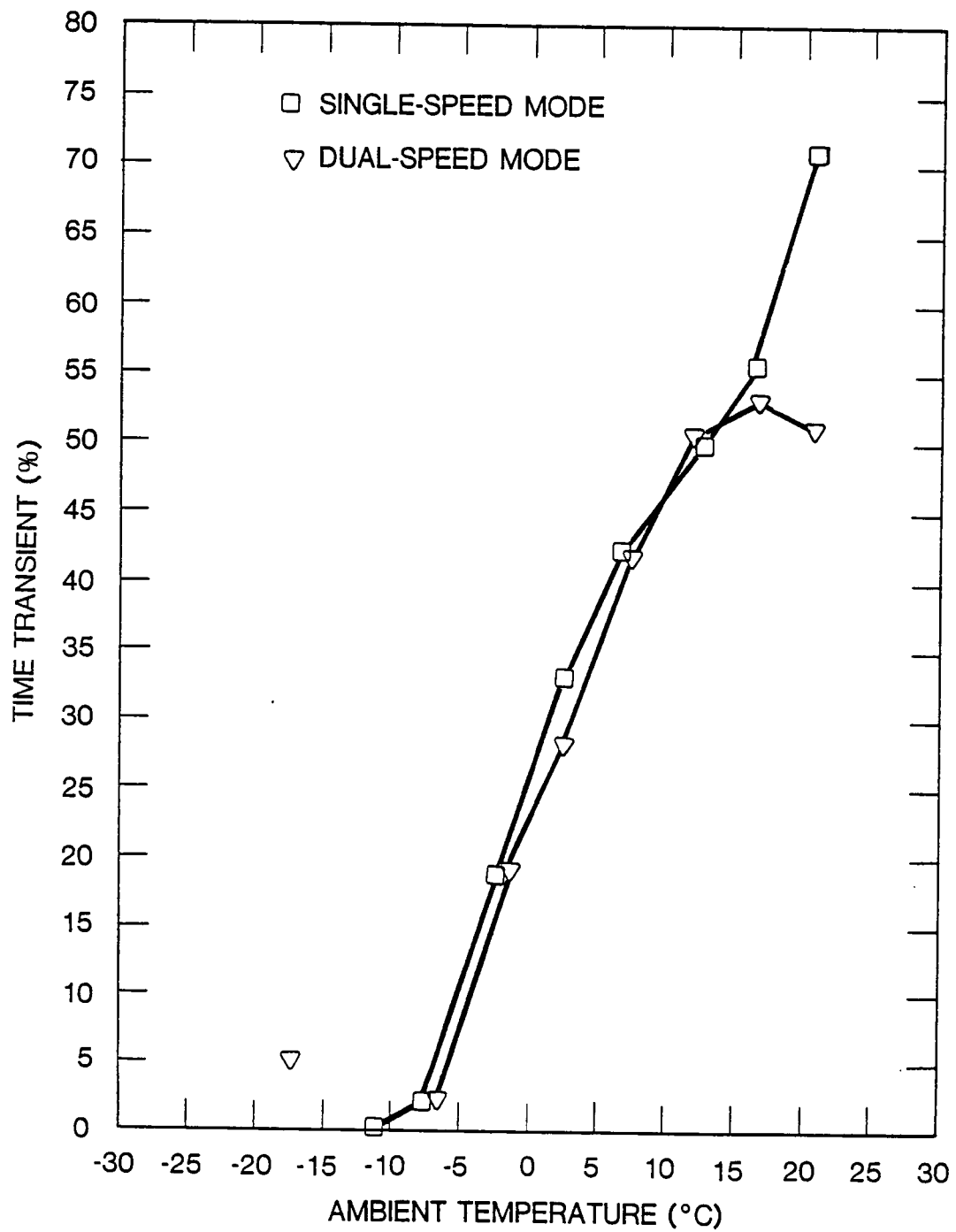


Figure 3.3 Comparison of Percent Time Transient for Single and Dual-Speed Modes

3. For bins with temperature above approximately 5°C the off-cycle crankcase energy consumption begins to affect the overall COP values. For the warmer bins this effect is seen to be substantial.

4. The dual-speed mode is seen from Figures 3.2 and Sections A.1 and A.2 to have experienced colder ambient temperatures than the single-speed mode. However, the dual-speed mode experienced a greater percentage of its operating hours above an outdoor ambient temperature of 0°C.

Tables 3.7 and 3.8 give an energy input breakdown over the entire heating season for the single and dual-speed modes respectively. Also included in these tables is a percentage of total, both inclusive and exclusive of normal strip heat (I^2R), for the different input modes. The overall heating season performance factor (HSPF) for the dual-speed mode was 2.17 while for the single-speed mode was 2.11. The HSPF without normal strip was 2.26 for the dual-speed mode and 2.19 for the single-speed mode. The HSPF without off-cycle crankcase input was found to be 2.23 for the dual-speed mode and 2.15 for the single-speed mode. These values can be calculated by using the energy outputs given in the appendix, Sections A.1 and A.2, along with the inputs as given in Tables 3.7 and 3.8.

Table 3.7 Energy Input Breakdown Over the Heating Season
for the Single-Speed Mode

Energy Input Description	Input (Kw-hr)	% of Total (Inclusive of Normal I ² r)	% of Total (Exclusive of Normal I ² r)
transient mode	309.2	18.0	19.3
normal mode	1203.7	70.1	75.2
defrost mode	13.5	0.8	0.8
off-cycle crankcase heater	30.7	1.8	1.9
normal I ² r	118.2	6.9	---
defrost I ² r	42.7	2.5	2.7
total	1718.0		

Table 3.8 Energy Input Breakdown Over the Heating Season
for the Dual-Speed Mode

Energy Input Description	Input (Kw-hr)	% of Total (Inclusive of Normal I ² r)	% of Total (Exclusive of Normal I ² r)
transient mode	263.9	21.0	22.7
normal mode	808.4	64.4	69.4
defrost mode	13.6	1.1	1.2
off-cycle crankcase heater	33.4	2.7	2.9
normal I ² r	89.9	7.2	---
defrost I ² r	45.2	3.6	3.9
total	1254.4		

Given in Appendix A, Sections A.3 and A.4 on pages 103-104, are the compressed raw data sets for the dual-speed mode in low speed compressor hours and high speed hours, respectively. That is, Section A.3 is for hours where the compressor ran only in low speed

for that hour while Section A.4 is for hours where the compressor ran only in high speed for that hour. Section A.8 on pages 112-116 gives a listing of the computer program used to generate Section A.3 while Section A.9 on pages 117-121 gives a listing of the computer program used to generate Section A.4. Comparing these two to Section A.2 which is the dual-speed mode for combined hours, one can see that there were some hours over the heating season where the system ran in both low and high speed compressor mode for the same hour. This factor was taken into account when proportioning the off-cycle crankcase energy consumption for Sections A.3 and A.4. Also, obvious from Sections A.3 and A.4, is that the system ran mostly in low speed compressor mode for the warmer temperature bins or lighter load conditions and mainly in high speed compressor mode for the cooler temperature bins or higher load conditions.

Table 3.9 shows a summary of the different heating degradation factors as given in Sections A.1-A.4. Each mode has a transient, defrost, normal I^2R , and crankcase degradation factor, based on both normal-mode performance (COPN) and manufacturer's steady-state performance (COPSS). These heating degradation factors are defined in Appendix A, Section A.10 on page 124. As can be seen from this summary, the dual-speed combined mode has consistently higher degradation factors than the single-speed mode. These degradations will be discussed in more detail in the following sections.

Table 3.9 Degradation Factors for the Heating Season

Description	transient ^a (%)	defrost ^a (%)	normal I ² r ^b (%)	off-cycle crankcase heater ^a (%)
Single-speed mode				
based on COPN	2.8	3.9	6.9	1.9
based on COPSS	0.8	2.8	6.7	1.8
Dual-speed mode (combined)				
based on COPN	3.6	5.5	7.2	2.9
based on COPSS	1.8	4.2	7.2	2.9
Dual-speed mode (low speed hours only)				
based on COPN	8.2	0.0	0.0	7.6
based on COPSS	8.1	0.0	0.0	8.6
Dual-speed mode (high speed hours only)				
based on COPN	1.6	6.6	10.3	0.8
based on COPSS	-0.5	6.0	9.9	0.8

^a Relative to total energy use exclusive of normal I²r
^b Relative to total energy use

3.4 Comparison of Test Results to Steady-State Performance

Referring to Figures 3.4-3.6, a comparison of the test results to the steady-state performance can be made. Figure 3.4 which is for the single-speed mode shows the COP line generated by the steady-state data to be less than the normal COP line for temperatures less than approximately 7°C and greater for temperatures above 7°C. A similar conclusion can be reached by referring to Figures 3.5 and 3.6 which are for the dual-speed mode. Because of this observation it can be concluded that frosting of the outdoor unit had no measurable impact on overall performance. Steady-state percent degradations are given in Table 3.9.

3.5 Effects of Strip Heat Upon Performance

The need for supplemental electric resistance heat, or strip heat (I^2R), whether due to the heating capacity of the system being unable to deliver the required heating load, called normal I^2R , or due to defrosting requirements, called defrost I^2R , contributes a degradation to operating performance. This section discusses the degradation due to normal strip heat while the next section covers the degradation due to defrosting effects. Figure 3.4 shows a comparison of different COP's for the single-speed mode while Figure 3.5 is the corresponding dual-speed comparison. From Figure 3.4 for the single-speed mode the effect of normal strip heat can be seen by comparing the overall COP curve with that of the overall COP without normal I^2R . For temperatures less than 0°C the overall COP

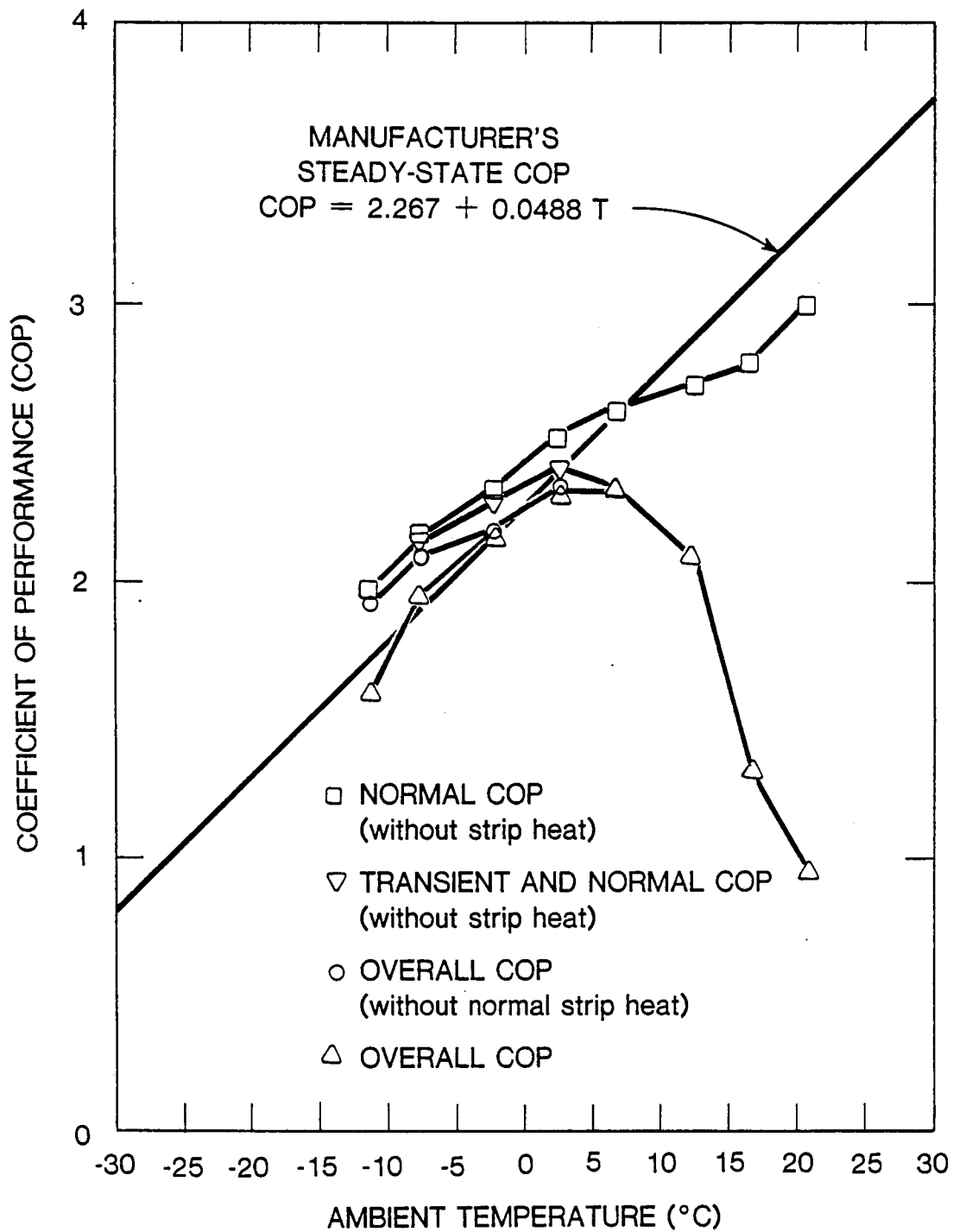


Figure 3.4 Comparison of Different Heating COP's for the Single-Speed Mode

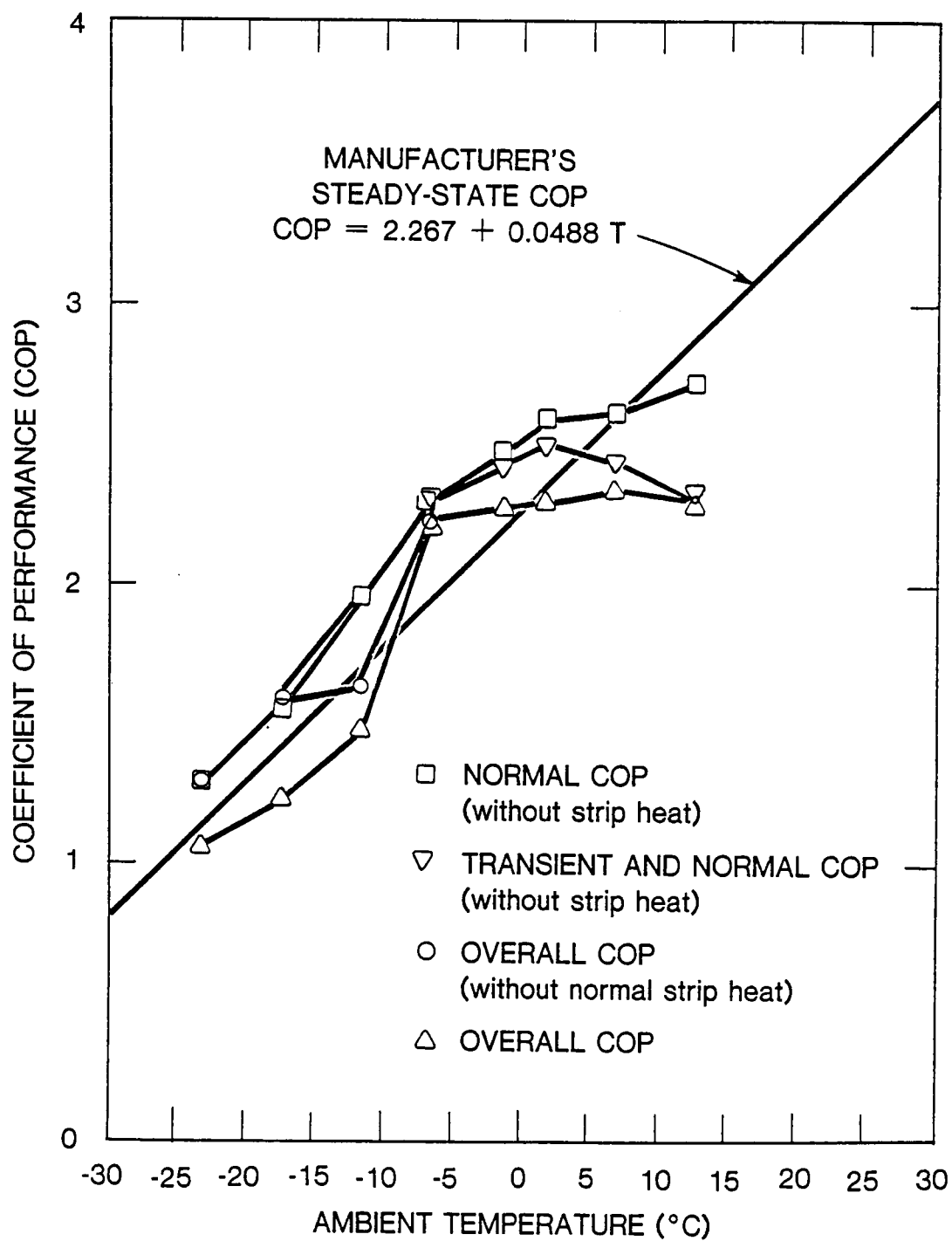


Figure 3.5 Comparison of Different Heating COP's for the Dual-Speed Mode, High Speed Compressor Hours

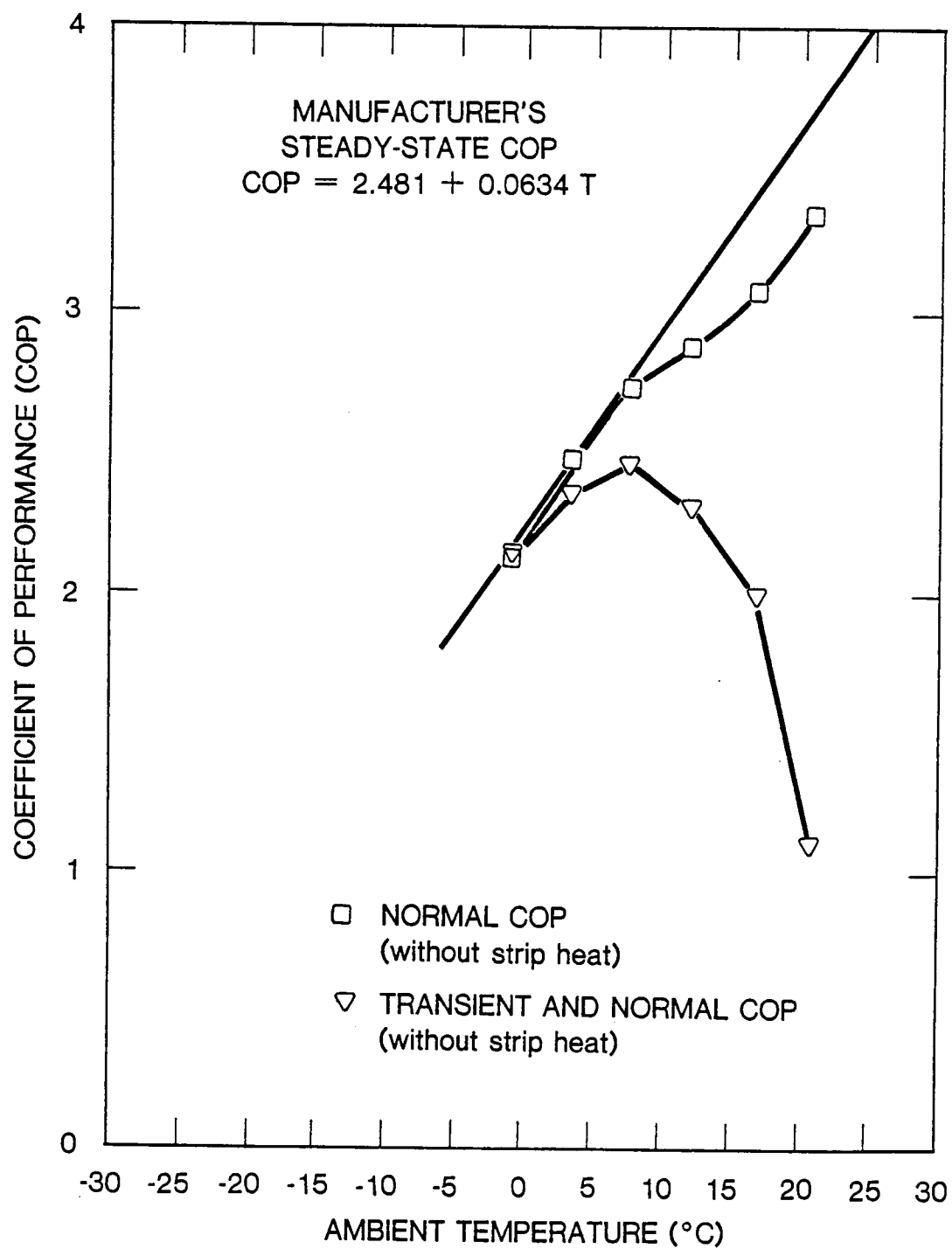


Figure 3.6 Comparison of Different Heating COP's for the Dual-Speed Mode, Low Speed Compressor Hours

without normal strip is greater than that of the overall COP. A similar conclusion can be drawn from Figure 3.5 for the dual-speed mode. Sections A.1 and A.2 give the percent degradation due to normal strip heat as 6.9 for the single-speed mode and 7.2 for the dual-speed mode.

3.6 Effects of Defrosting Upon Performance

As was discussed earlier, defrosting greatly reduces the overall performance of the heat pump system. When the accumulation of frost on the coil of the outdoor unit is greatly increasing the air-side pressure drop across the coil, the system switches to the defrost mode. In this mode, the system acts as an air-conditioner, removing heat from the conditioned space to melt away the frost. To maintain indoor comfort the supplemental electric strip heaters are energized. The net effect is very little heat flow to the conditioned space.

Sections A.1-A.4 show the calculated COP values and the percent time in defrost mode for the various bin temperatures. All defrost COP's are seen to be well below 1.0. Section A.2 shows the dual-speed mode to have spent a slightly higher percentage of time in defrost than the single-speed mode. Table 3.9 gives the percent degradation due to defrost to be 3.9 for the single-speed mode and 5.5 for the dual-speed mode based on normal-mode performance.

3.7 Effects of Transient Stage Upon Performance

As was previously discussed, when the system runs in the transient stage, that is the first four minutes of each on cycle, the heating capacities attained are not as high as they would be if the system was operating in its normal or steady-state mode. Thus the system has a lower coefficient of performance in the transient stage than in the normal stage since the power inputs are about the same and the output energy is not as high. Figure 3.7 shows a comparison of the transient COP and normal COP without crankcase and stripheat for the single-speed mode while Figure 3.8 is the corresponding comparison for the dual-speed mode. From both these figures it is evident that the system had a higher COP in the normal stage than in the transient stage. This difference in performance for the two stages leads to a degradation in performance based on COPN that was quantified to be 2.8% for the single-speed mode and 3.6% for the dual-speed mode. The corresponding degradation factors based on COPSS are 0.8% for the single-speed mode and 1.8% for the dual-speed mode.

A comparison of the normal COP's without crankcase and strip heat for the single and dual-speed modes is given in Figure 3.9. From this it is seen that the dual-speed mode had a higher COP than the single-speed mode in the normal stage of operation. A comparison of the transient COP's without crankcase for the single and dual-speed modes as given in Figure 3.10 offers similar conclusions regarding the transient stage.

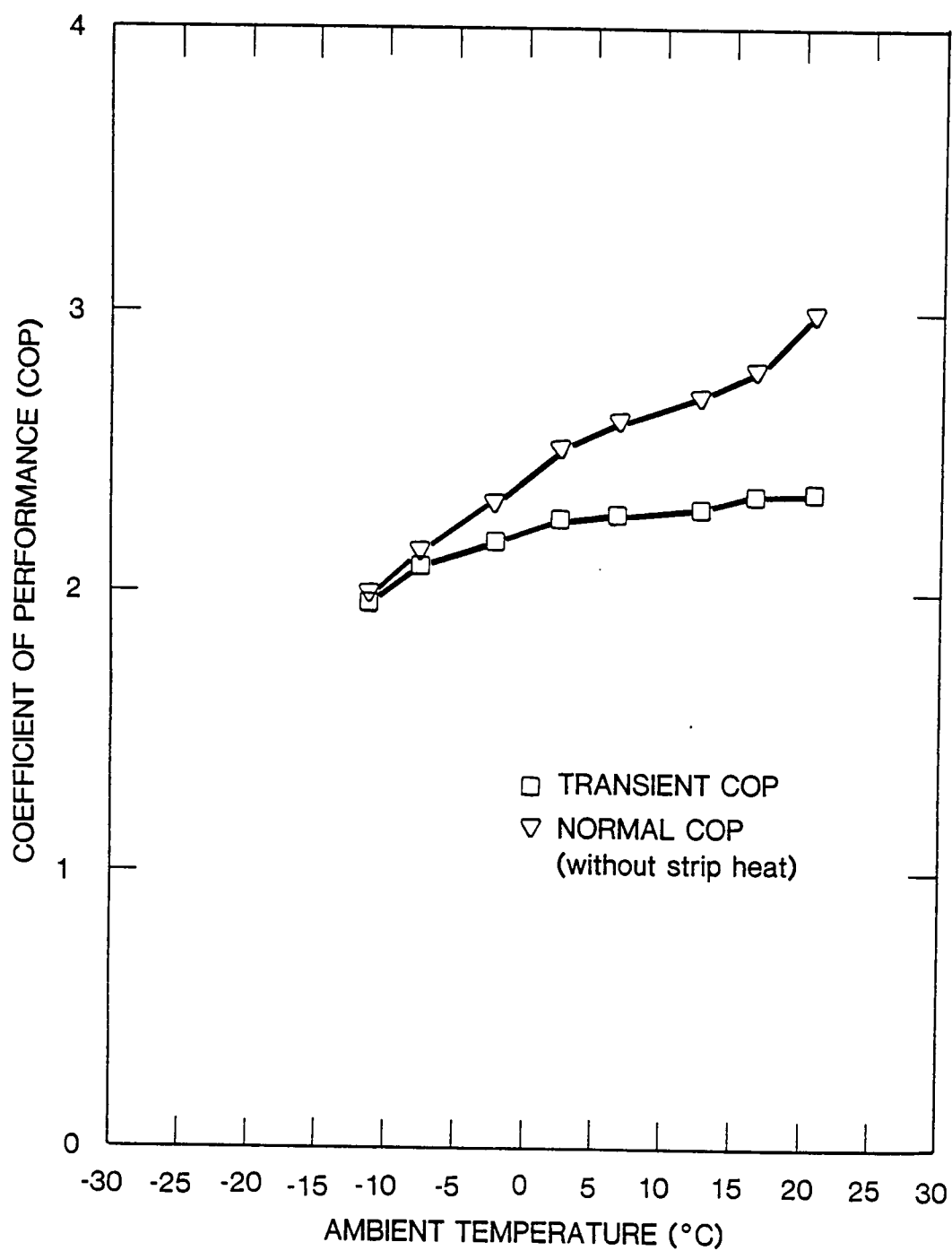


Figure 3.7 Comparison of Transient and Normal COP's without Crankcase for the Single-Speed Mode

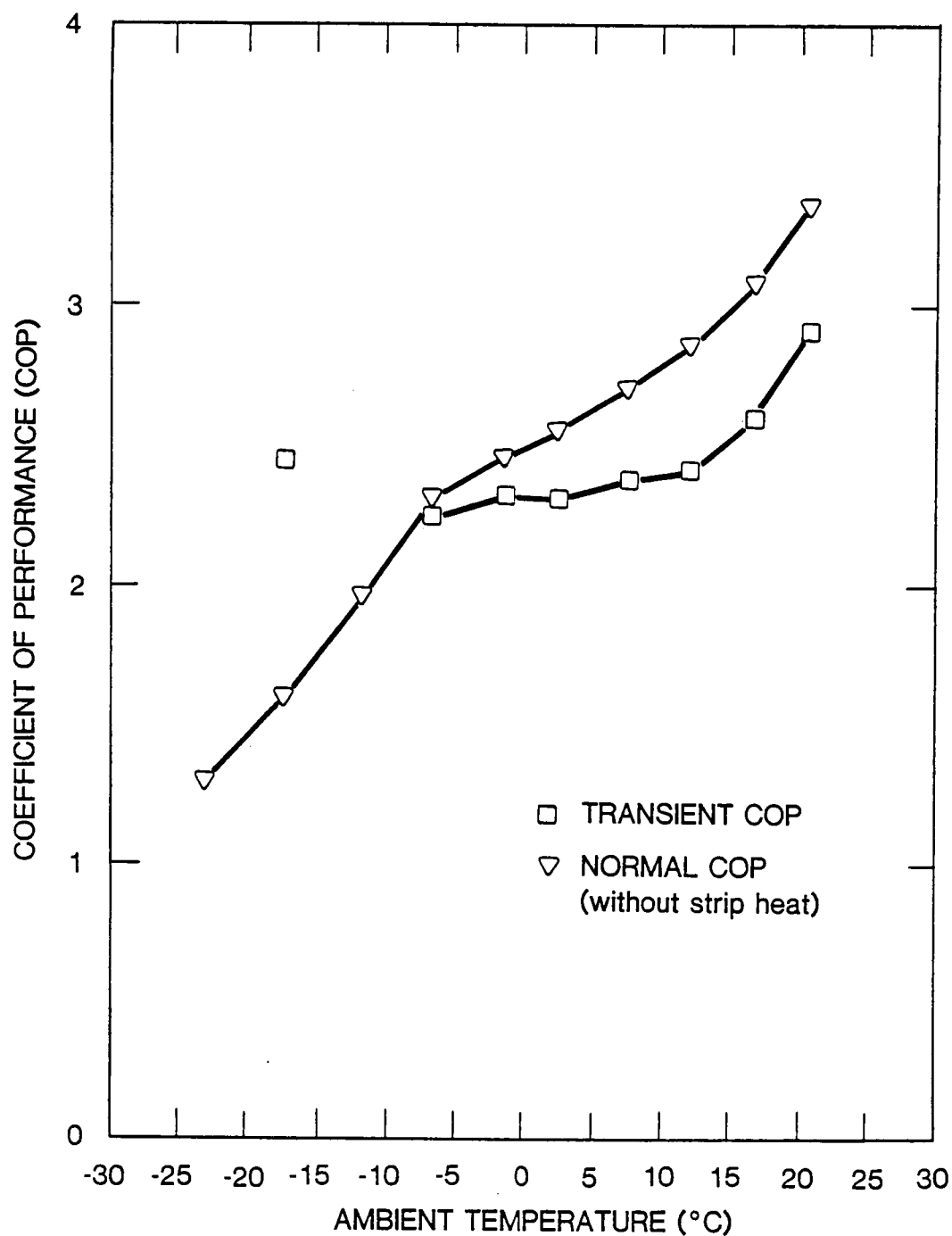


Figure 3.8 Comparison of Transient and Normal COP's without Crankcase for the Dual-Speed Mode

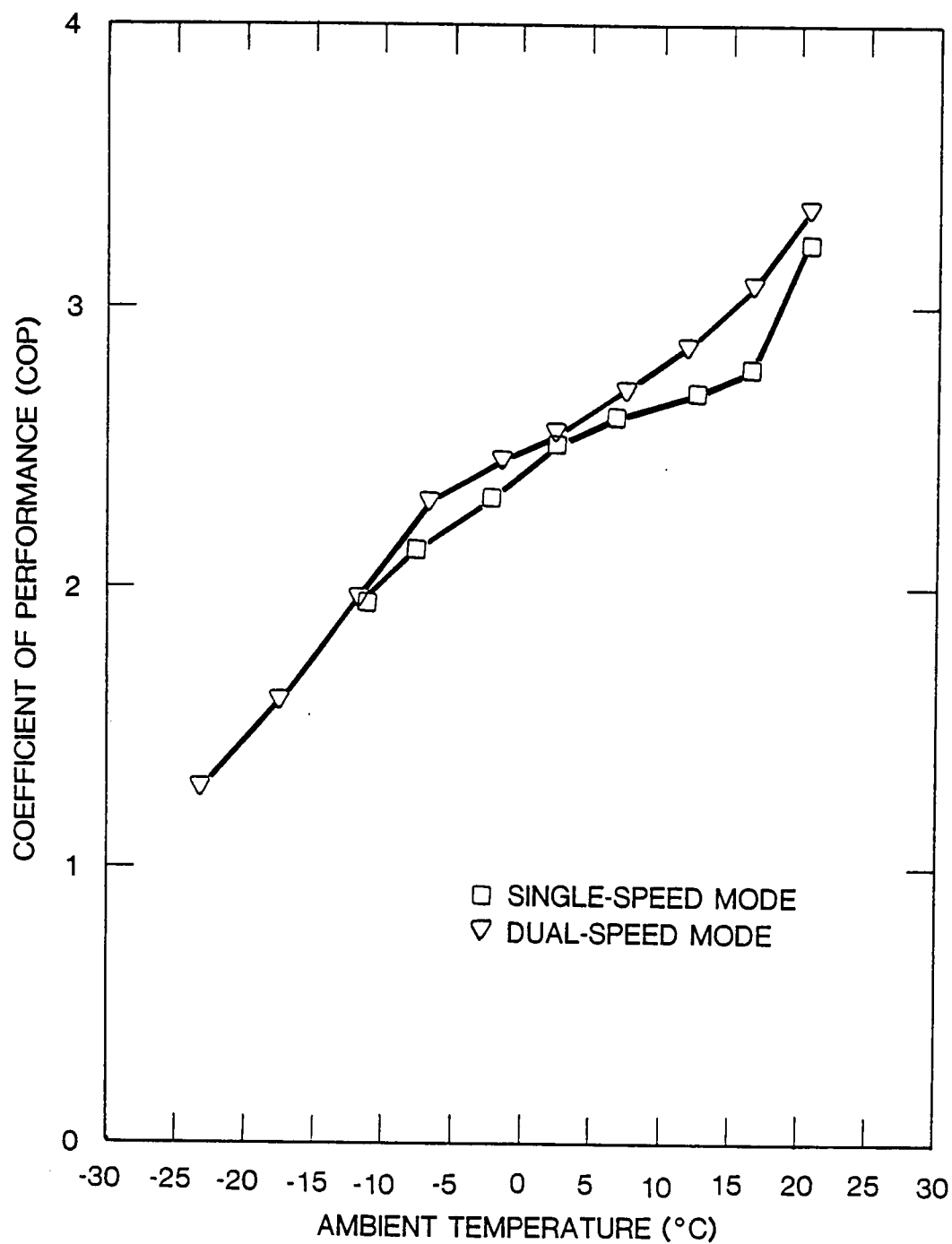


Figure 3.9 Comparison of Normal COP's without Crankcase and Strip Heat for the Single and Dual-Speed Modes

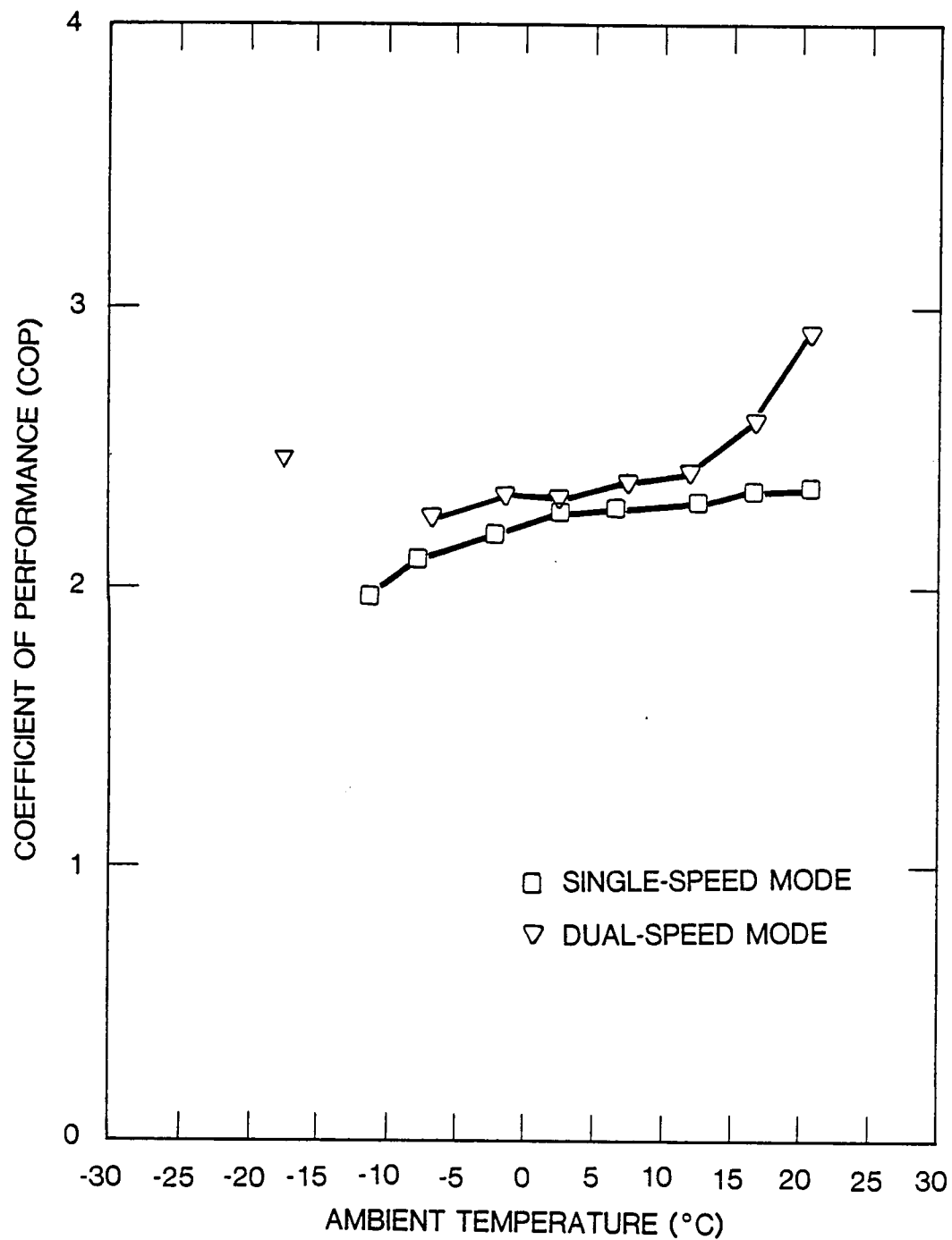


Figure 3.10 Comparison of Transient COP's (without Crankcase) for the Single and Dual-Speed Modes

The fact that the dual-speed mode had a higher transient degradation than the single-speed mode will now be discussed. Even though this contradicts what one would intuitively expect, the reason for it can be shown by examining Sections A.1 and A.2. Comparing the number of hours in each bin for both the dual-speed and single-speed data shows the dual-speed experienced a greater percentage of hours in the warmer or lighter load temperature bins. Thus it experienced more cyclic type load conditions and this contributed to the transient input being a greater percentage of the total input. This caused the dual-speed mode transient degradation to be higher than the single-speed mode.

3.8 Effects of Off-Cycle Crankcase Heater Energy Consumption Upon Performance

The effect of the off-cycle crankcase energy input is most noticeable in the higher temperature, or lower load bins. This is due to the system having a higher percentage of crankcase input to total input under these conditions. Since the system gets no useful energy output from this crankcase input it degrades the overall performance of the unit. Sections A.1-A.4 show the total crankcase input for each bin along with the percent degradation due to crankcase for each. Table 3.9 gives overall degradations of 1.9% for the single-speed mode and 2.9% for the dual-speed mode based on COPN. As seen in Tables 3.7 and 3.8 the single-speed mode had 1.97% of its energy input (exclusive of I^2R) used by the crankcase heater,

while for the dual-speed mode the amount was 3.0%. This contributes to the dual-speed degradation due to off-cycle energy being higher than the single-speed value.

3.9 Comparison of Demand and Timer Defrost System

As mentioned earlier, another objective of the testing run on this heat pump was to compare the demand defrost control system used on this unit to the timer defrost control used on the system analyzed in Reference 10. A discussion of the demand defrost control appears in the introductory paragraph of this chapter. The timer defrost control used on the other system was set on a 90 minute cycle with a maximum allowable defrost period of 10 minutes (10).

Table 3.10 contains percentage of time in defrost along with average bin relative humidity vs. bin temperature for the three systems under discussion, the system from Reference 10, single-speed operation mode, and dual-speed operation. As seen from this table, the demand defrost control appears to be more efficient since the system is required to run a smaller percentage of its time in defrost for both the single-speed and dual-speed modes.

Tables 3.11 and 3.12 estimate the input energy savings that the demand defrost system may have saved opposed to using the timer defrost system under the same conditions. Table 3.11 is for the single-speed mode and Table 3.12 is for the dual-speed mode. These tables estimate the input savings by how much additional energy the system would consume if it operated the same percent time in defrost

for each bin as the Reference 10 unit did. Seasonal totals for the input energy savings were 366.7 Kw-hr and 169.1 Kw-hr for the single-speed mode and dual-speed mode, respectively.

Table 3.10 Comparison of % Time in Defrost vs.
Bin Temperature

Description	Bin Temperature (°C)				
	-15/-10	-10/-5	-5/0	0/5	5/10
Reference 10					
% time defrost	9.31	6.78	7.00	4.94	0.97
avg. bin R.H.	76.0	64.5	68.4	67.8	65.3
Single-speed					
% time defrost	0.50	0.64	1.24	0.68	0.00
avg. bin R.H.	67.1	60.0	56.9	58.2	48.1
Dual-speed					
% time defrost	4.10	0.82	1.70	1.80	0.11
avg. bin R.H.	69.2	61.6	58.4	60.5	61.8

Table 3.11 Demand Defrost System Input Energy Savings
for the Single-Speed Mode

Savings (Kw-hr)	-15/-10	-10/-5	-5/0	0/5
Defrost input	11.5	19.5	34.4	21.2
Defrost strip	43.9	64.1	106.6	65.6
Total input	55.4	83.6	141.0	86.8

Table 3.12. Demand Defrost System Input Energy Savings
for the Dual-Speed Mode

Savings (Kw-hr)	-15/-10	-10/-5	-5/0	0/5	5/10
Defrost input	1.6	8.4	16.4	9.7	3.1
Defrost strip	6.7	31.0	54.6	30.1	7.4
Total input	8.3	39.4	71.0	39.8	10.5

CHAPTER IV

COOLING SEASON PERFORMANCE

4.1 Introduction

The results of tests run during four summer months over the 1985 cooling season and analyses of the test data for both modes of operation are described in this section. Table 4.1 lists the monthly data sets and the number of hours included in each for the single-speed mode. Table 4.2 lists the dual-speed data sets. A detailed tabulation of the compressed raw data set and test results is given in Appendix A, Sections A.5 and A.6 on pages 105-106, for 5°C-wide temperature bins. The tables are for the single and dual-speed modes, and are for the entire cooling season. The following sections will discuss overall performance, test results compared to steady-state performance, effect of the transient stage upon performance, and effect of off-cycle crankcase heater input upon performance.

During the cooling season an additional indoor thermostat stage was used to control whether the system ran in low or high speed compressor operation while in the dual-speed mode. The activation of the first thermostat stage caused the system to come on in low speed. If the system was unable to carry the cooling load the second thermostat stage was activated, causing the unit to shut-off for three minutes and then come back on in high speed. That is, the system always came on first in low speed for dual-speed mode.

Table 4.1 Cooling Season Monthly Data Sets for
Single-Speed Mode

Month	Days Included In Data Set	Data* Hours
June 1985	June 18-24	168
July 1985	July 2-7,16-21,30-31	325
August 1985	August 1-4,13-19,27-31	370
September 1985	September 1-2,10-15	180

* Total hours exclusive of those hours with missing or suspect data

Table 4.2 Cooling Season Monthly Data Sets for
Dual-Speed Mode

Month	Days Included in Data Set	Data* Hours
June 1985	June 11-16,26-30	254
July 1985	July 9-13,23-25	184
August 1985	August 6-11,21-25	264
September 1985	September 4-8,17-22	261

* Total hours exclusive of those hours with missing or suspect data

4.2 Steady-State Performance Base

As with heating, for cooling the only source available for determining the steady-state performance of the test heat pump was the manufacturer's rating. In Chapter 2, Tables 2.1 and 2.2 on page 8 give the cooling capacity for low and high speed compressor operation. Tables 4.3 and 4.4 show the given compressor motor inputs for low and high speed compressor operation. Determining the cooling capacities and compressor inputs by linearly extrapolating the manufacturer's data to the system's actual indoor coil air volume of 1050-1100 cfm and using field data to approximate the indoor and outdoor fan consumptions at different ambient temperatures, the steady-state performance values were calculated. Tables 4.5 and 4.6 show the low and high speed compressor steady-state data along with the calculated COP's for the different temperatures. Figure 4.1 shows the various data points for low speed and high speed compressor operation along with the best fit straight line calculated for both. In calculating the individual COP's for the different ambient temperatures for Tables 4.5 and 4.6 the following formula was used:

$$\text{COP} = \frac{\text{total cooling capacity} - \text{indoor fan input}}{\text{compressor input} + \text{indoor fan input} + \text{outdoor fan input}}$$

Table 4.3 Compressor Motor Input in Watts for Low Speed
Compressor Operation

Entering Indoor Wet Bulb (°F)	Indoor Coil Air Volume (cfm)	Air Temperature Entering Outdoor Coil (°F)			
		75	85	95	105
63	700	1320	1410	1510	1630
	800	1330	1420	1520	1650
	900	1340	1430	1540	1660
67	700	1350	1430	1540	1660
	800	1350	1440	1540	1660
	900	1360	1440	1550	1670
71	700	1370	1450	1560	1690
	800	1370	1460	1570	1690
	900	1380	1470	1570	1700

Table 4.4 Compressor Motor Input in Watts for High Speed
Compressor Operation

Entering Indoor Wet Bulb (°F)	Indoor Coil Air Volume (cfm)	Air Temperature Entering Outdoor Coil (°F)			
		85	95	105	115
63	1200	3110	3270	3430	3600
	1350	3130	3300	3480	3660
	1500	3160	3340	3520	3700
67	1200	3190	3360	3530	3690
	1350	3210	3380	3550	3720
	1500	3230	3400	3580	3740
71	1200	3280	3460	3640	3810
	1350	3300	3490	3660	3830
	1500	3320	3500	3680	3850

Table 4.5 Low Speed Compressor Steady-State Data

Ambient Air Temperature (°C)	Total Cooling Capacity (watts)	Compressor Input (watts)	Indoor Fan Input (watts)	Outdoor Fan Input (watts)	COP
23.89	7471	1360	506	320	3.19
29.44	6973	1440	506	320	2.85
35.0	6548	1560	506	320	2.53
40.56	6050	1680	506	320	2.21

Table 4.6 High Speed Compressor Steady-State Data

Ambient Air Temperature (°C)	Total Cooling Capacity (watts)	Compressor Input (watts)	Indoor Fan Input (watts)	Outdoor Fan Input (watts)	COP
29.44	11427	3170	506	320	2.73
35.0	10665	3340	506	320	2.44
40.56	9962	3500	506	320	2.19
46.11	9259	3660	506	320	1.95

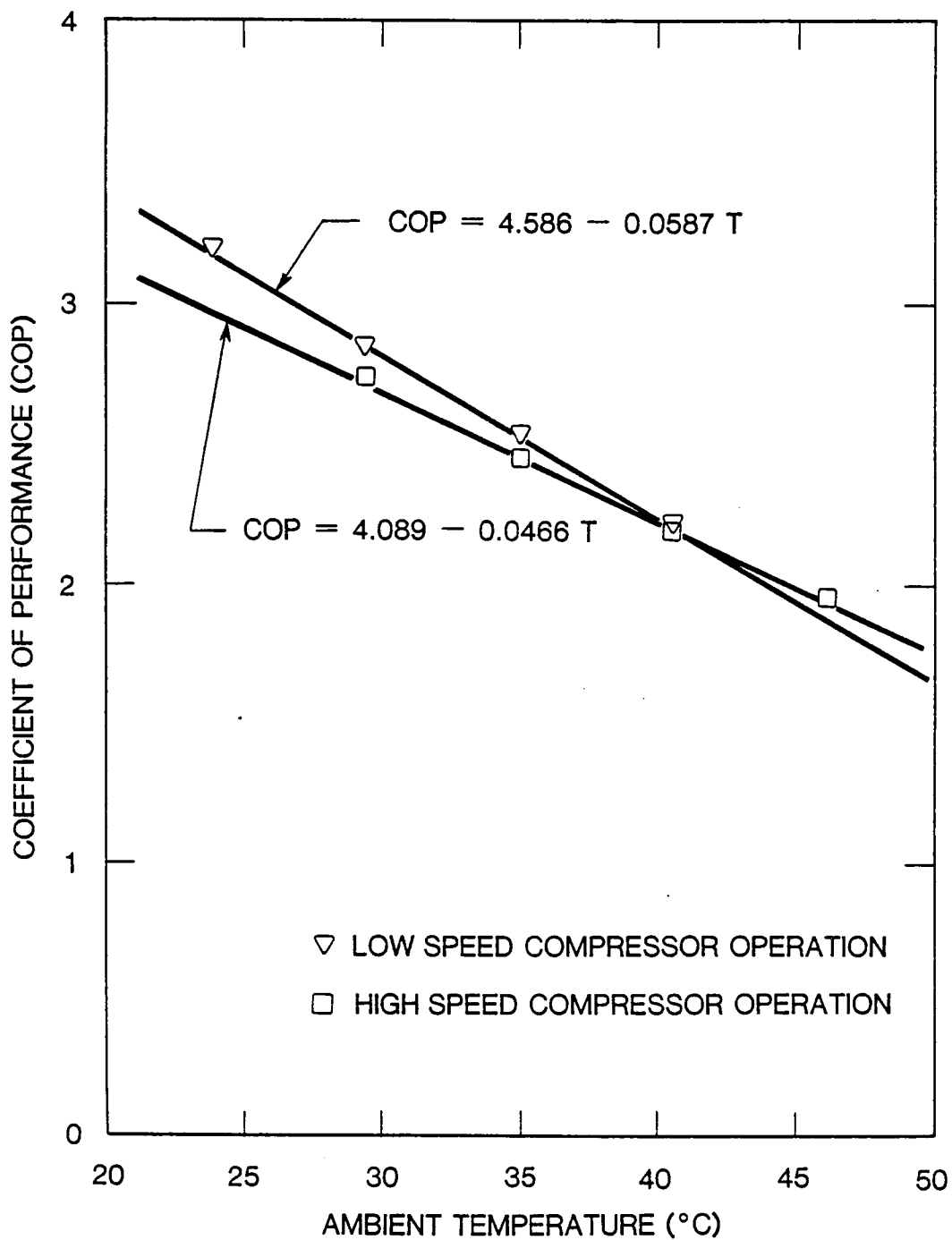


Figure 4.1 Manufacturer's Cooling COP vs. Ambient Temperature for Low and High Speed Compressor Operation

4.3 Test Results

In Appendix A, Section A.11 on pages 126-129 gives a listing of the computer program used to generate the single-speed mode's bin results given in Section A.5 on page 105. Section A.12 on pages 130-133 gives a listing of the computer program used to generate the dual-speed mode's bin results given in Section A.6 on page 106. Bin value descriptions for the cooling season are given in Section A.13 on pages 134-136. Figure 4.2 shows overall COP vs. bin temperature for both modes of operation. Figure 4.3 shows sensible heat ratio vs. bin temperature. From these two figures and the compressed raw data sets given in Sections A.5 and A.6 the following conclusions can be made:

1. The dual-speed mode is shown to have a higher performance value for all bins the two modes have in common.
2. The sensible heat ratio was higher for the dual-speed mode in all bins due to the lower flow rate of the refrigerant during low speed compressor operation.
3. The dual-speed mode ran almost entirely in low speed compressor operation for the entire cooling season. It had only 3.353 hours of high speed compressor operation for the cooling season.

Tables 4.7 and 4.8 give an energy input breakdown over the entire cooling season for the single and dual-speed modes respectively. Also included in these tables is a percentage of the total that each input contributes. The cooling season performance

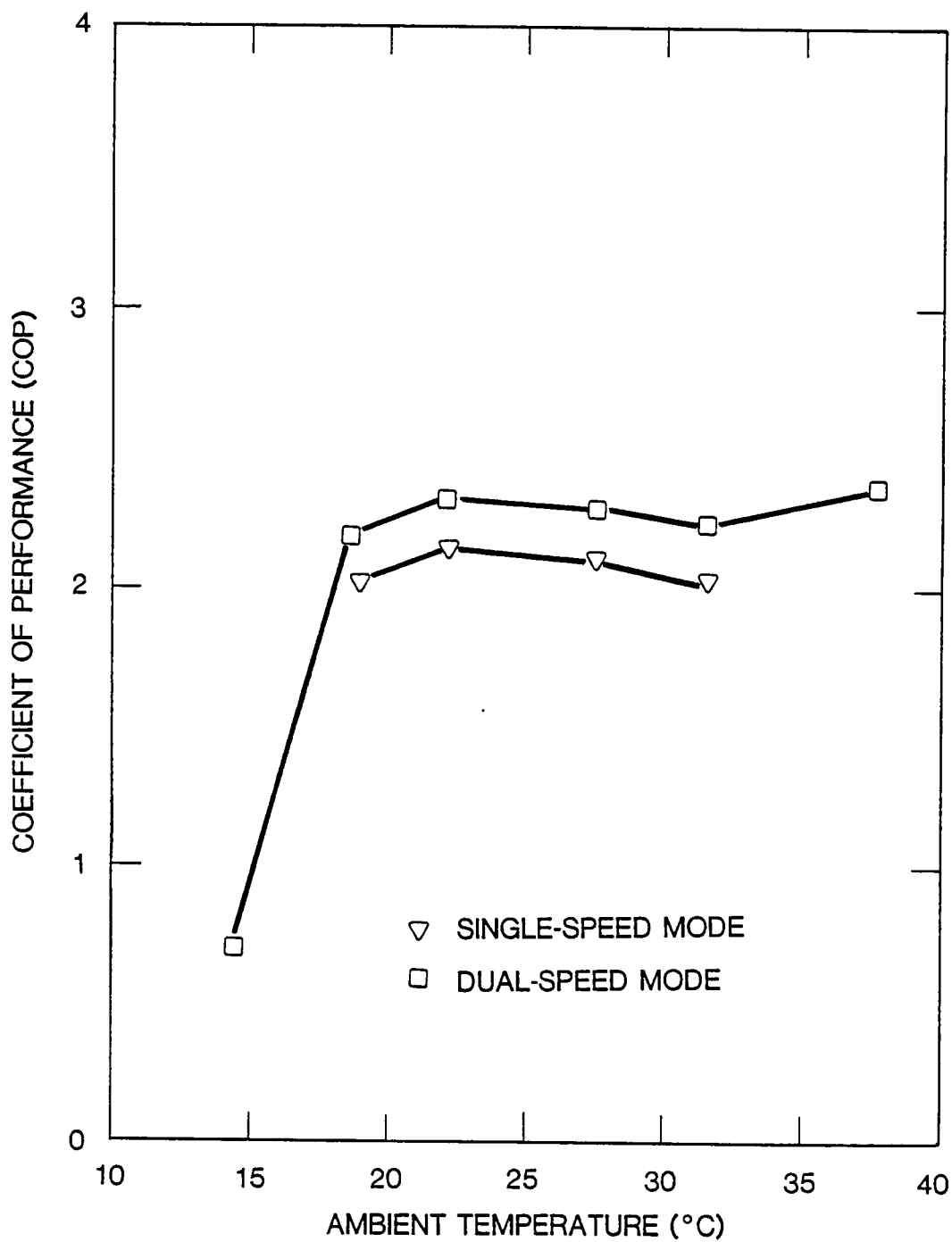


Figure 4.2 Comparison of Overall COP's (with Crankcase)
for Single and Dual-Speed Modes

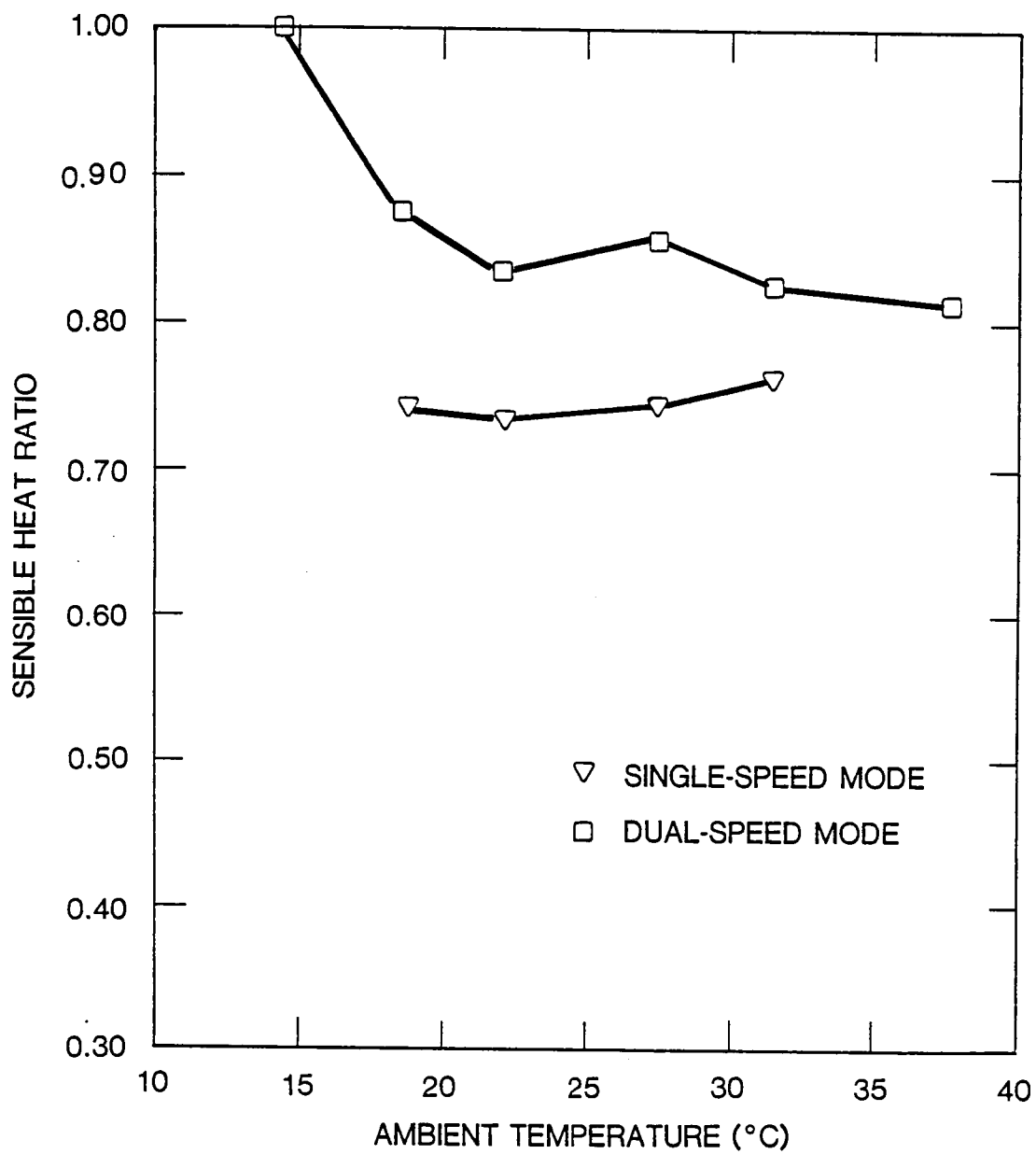


Figure 4.3 Comparison of Sensible Heat Ratios for Single and Dual-Speed Modes

factor (CSPF) for the dual-speed mode was calculated to be 2.27 while for the single-speed was found to be 2.09. The CSPF without crankcase was 2.34 for the dual-speed mode and 2.16 for the single-speed mode. These values can be verified by using the data given in Tables 4.7 and 4.8 for the energy inputs and Sections A.5 and A.6 for the energy outputs.

Table 4.7 Energy Input Breakdown Over the Cooling Season
for the Single-Speed Mode

Energy Input Description	Input (Kw-hr)	% of Total
transient mode	217.0	21.6
normal mode	755.2	75.1
off-cycle crankcase	32.8	3.3
total	1005.0	

Table 4.8 Energy Input Breakdown Over the Cooling Season
for the Dual-Speed Mode

Energy Input Description	Input (Kw-hr)	% of Total
transient mode	131.4	16.6
normal mode	633.5	80.0
off-cycle crankcase	26.5	3.34
total	791.4	

Table 4.9 shows a summary of the different cooling degradation factors as given in Sections A.5 and A.6. Each mode has a transient and off-cycle crankcase heater degradation factor, based on both normal-mode performance (COPN) and manufacturer's steady-state performance (COPSS). These cooling degradation factors are defined in Appendix A, Section A.13 on pages 134-136. As can be seen from this summary, the single-speed mode has higher transient degradation factors than the dual-speed mode with the off-cycle crankcase heater degradation factors being equal for the two modes.

Table 4.9 Degradation Factors for the Cooling Season

Description	Transient (%)	Off-cycle Crankcase Heater (%)
Single-speed mode based on COPN	2.7	3.3
based on COPSS	10.3	4.3
Dual-speed mode based on COPN	1.0	3.3
based on COPSS	7.1	4.3

4.4 Comparison of Test Results to Steady-State Performance

Referring to Figures 4.4 and 4.5, a comparison of the test results to the steady-state performance can be made. Figure 4.4 shows COP data obtained from the manufacturer along with the normal COP obtained from the test data for the single-speed mode. By

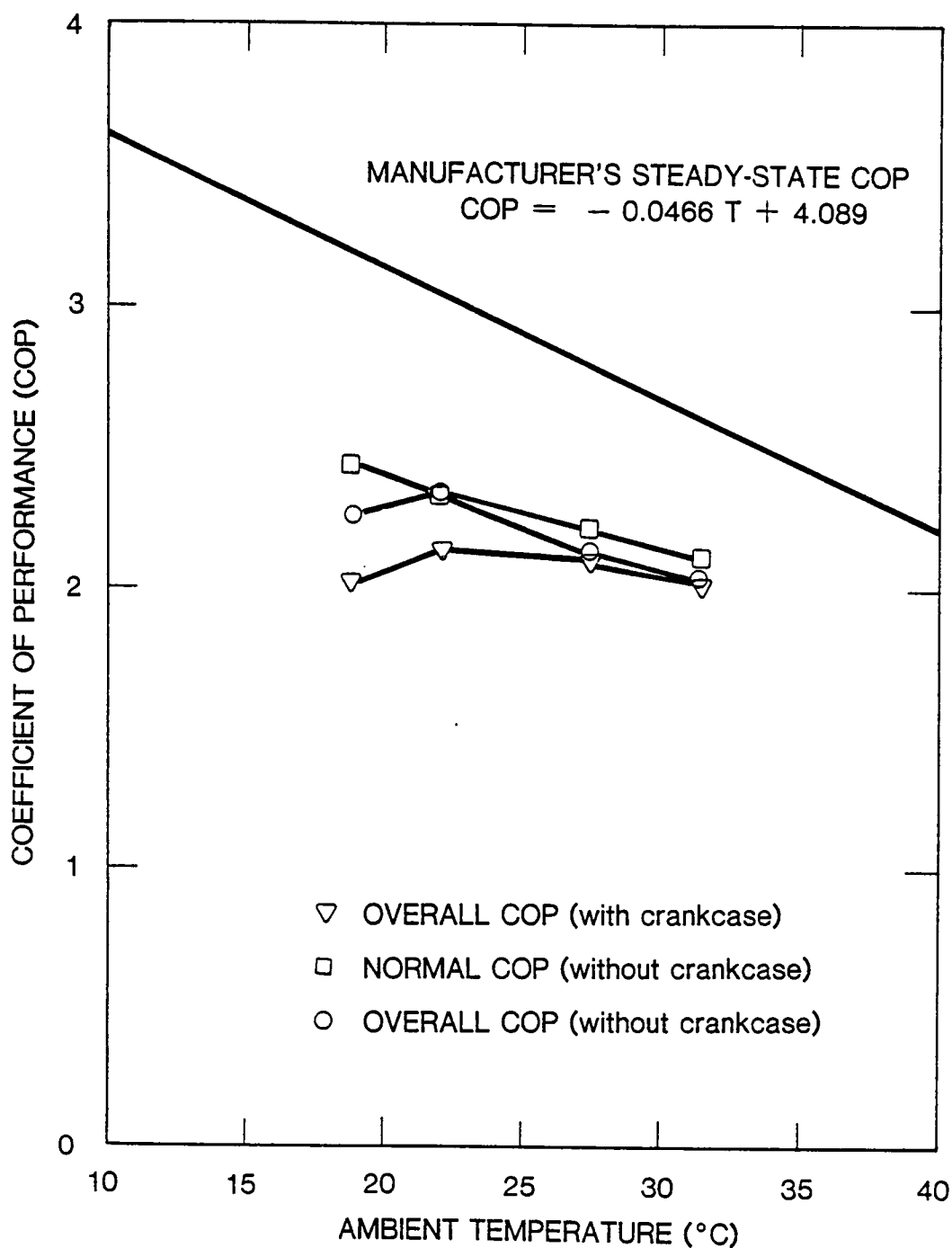


Figure 4.4 Comparison of Different Cooling COP's for the Single-Speed Mode

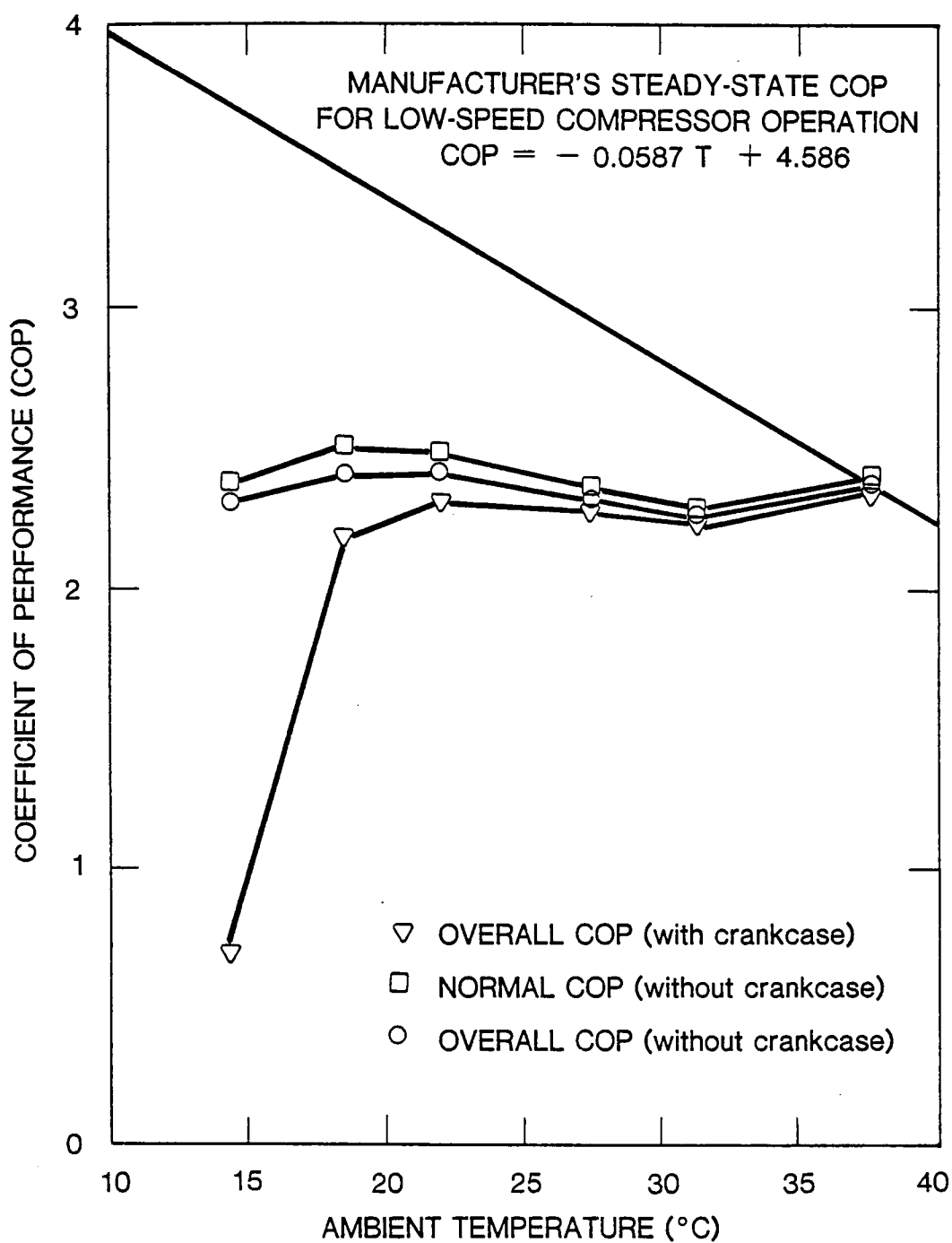


Figure 4.5 Comparison of Different Cooling COP's for the Dual-Speed Mode

comparing these two COP's it can be concluded that the cooling efficiency given by the manufacturer for high speed compressor operation is higher than was ever achieved for the test heat pump system. Figure 4.5 shows the COP data obtained from the test data for the dual-speed mode. Again it can be concluded the manufacturer's cooling COP for low speed compressor operation is higher than was achieved in the test heat pump system, although the two appear to be nearly equal at approximately 37.5°C.

4.5 Effects of Transient Stage Upon Performance

As was previously discussed, during the first four minutes of each cycle the system is running in its transient stage and has a lower cooling capacity than when it is operating in its normal or steady-state mode. Thus the transient stage contributes to a lower coefficient of performance and a degradation from the normal performance. Figure 4.6 shows a comparison of the transient and normal COP's without crankcase for the single-speed mode while Figure 4.7 is the corresponding comparison for the dual-speed mode. From these it is seen that the normal COP is always greater than the transient COP. Figures 4.8 shows a comparison of percent time transient for the single and dual-speed modes. From this it is seen that except for the 20 to 25°C temperature bin the dual-speed mode, which operated primarily in low speed, has a lower percent time in transient than the single-speed mode. Figure 4.9 shows a comparison of normal COP's without crankcase for single and dual-speed modes. It shows that the dual-speed mode had a higher normal COP than the single-speed mode. Figure 4.10 shows a comparison of transient COP's without crankcase for the two modes. As can be observed in Table 4.9, based on normal-mode performance the single-speed mode is seen to have a transient degradation factor of 2.7% while the dual-speed mode's transient degradation factor was 1.0%. The corresponding degradation values based on the steady-state COP were 10.3% and 7.1%.

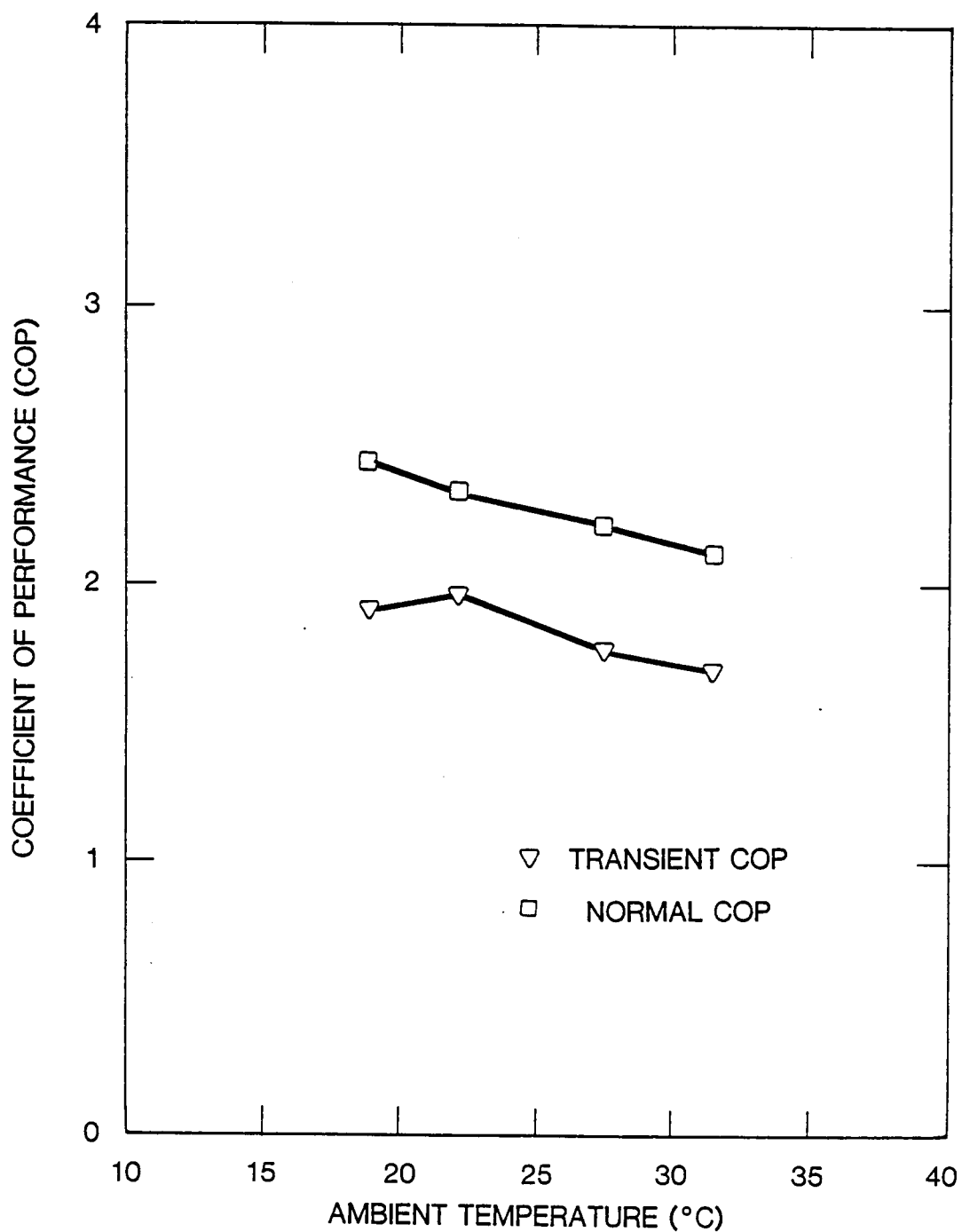


Figure 4.6 Comparison of Transient and Normal COP's without Crankcase for the Single-Speed Mode

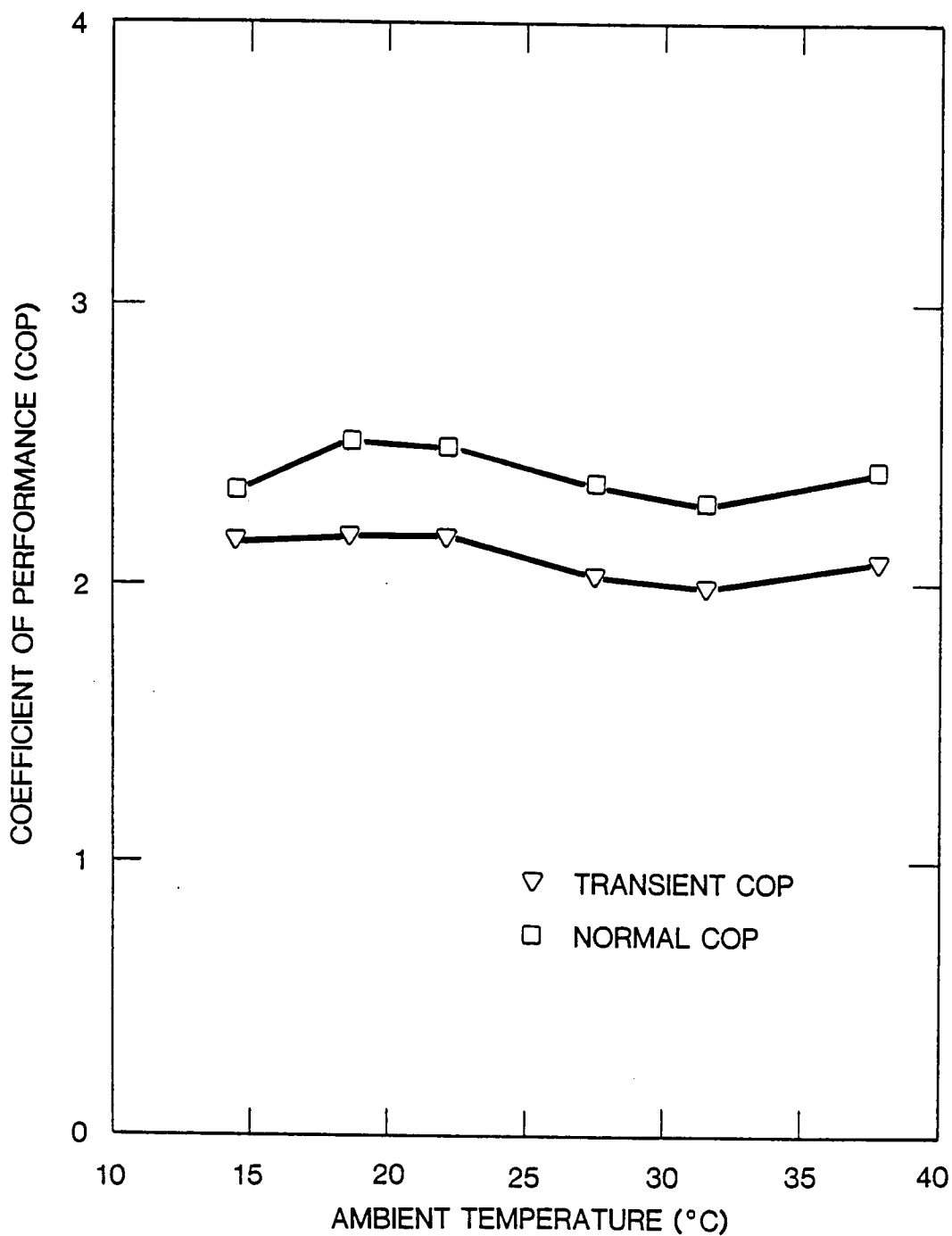


Figure 4.7 Comparison of Transient and Normal COP's without Crankcase for the Dual-Speed Mode

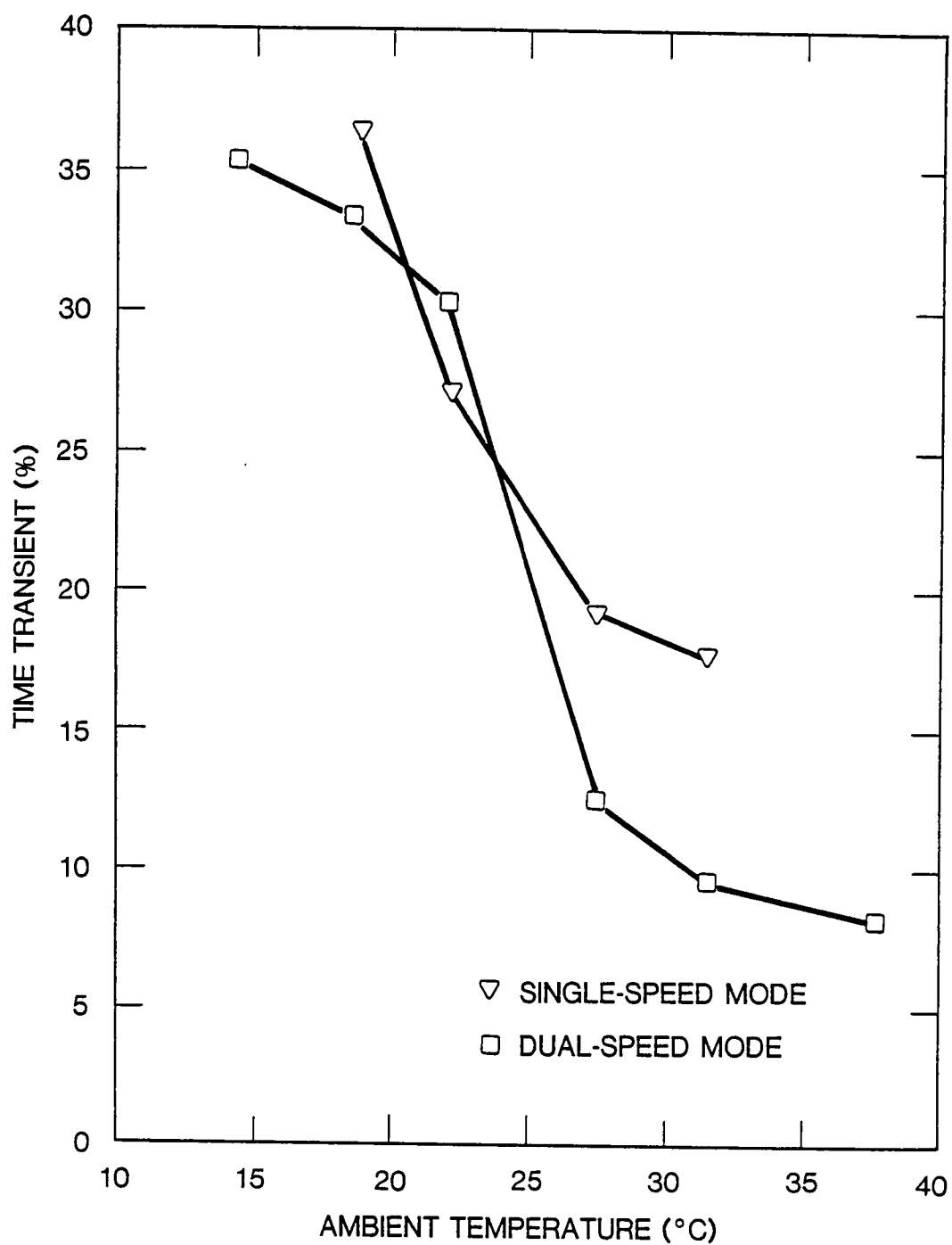


Figure 4.8 Comparison of % Time Transient for the Single and Dual-Speed Modes

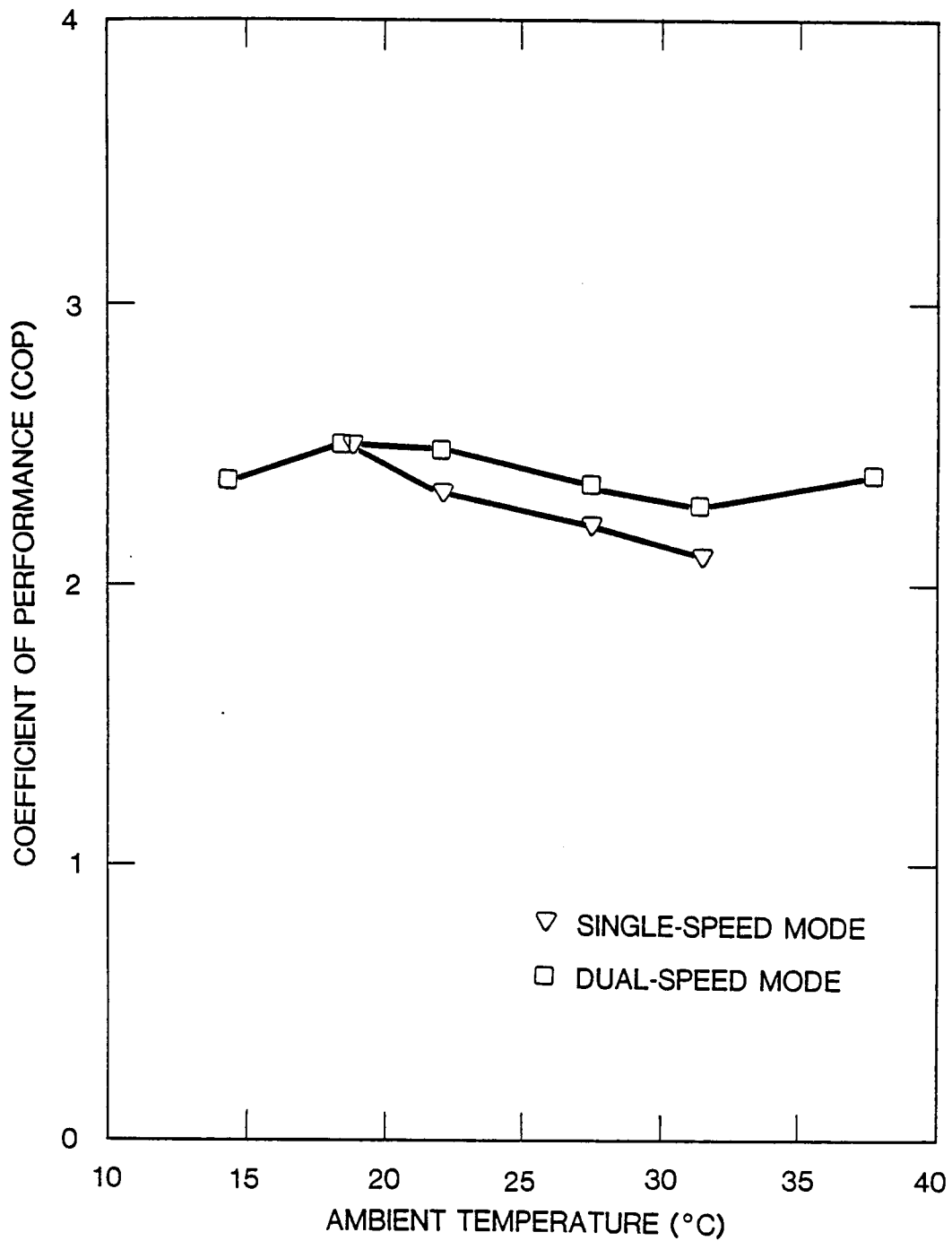


Figure 4.9 Comparison of Normal COP's (without Crankcase)
for the Single and Dual-Speed Modes

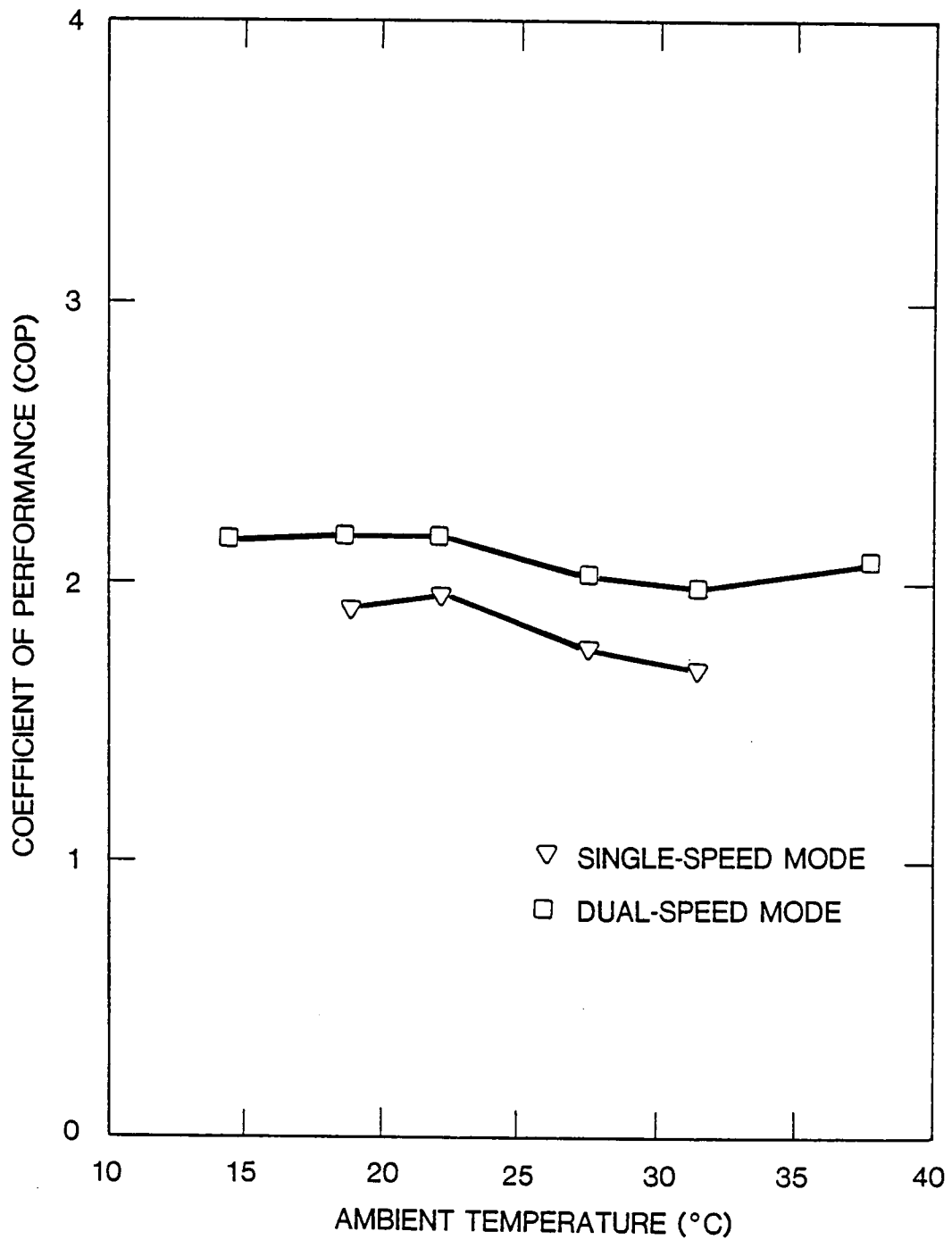


Figure 4.10 Comparison of Transient COP's (without Crankcase) for the Single and Dual-Speed Modes

4.6 Effects of Off-Cycle Crankcase Heater Energy Consumption Upon Performance

Figures 4.4 and 4.5 show a comparison of different COP's for the single and dual-speed modes respectively. As can be seen from these two figures along with the data given in Sections A.5 and A.6, off-cycle effects of the crankcase heater upon performance are greater for the cooler bins or lighter load conditions. This effect is substantial for the dual-speed mode as can be seen by comparing overall COP without crankcase and overall COP in Figure 4.5. A more gradual effect is seen for the single-speed mode. The reason the degradation for the dual-speed mode seems more severe is that the single-speed mode had no operating time at temperatures below 15°C. Both the single and dual-speed modes are seen from Table 4.9 to have a normal-based crankcase degradation factor of 3.3%. The corresponding steady-state-based crankcase degradation factors are seen to be 4.3% for both.

CHAPTER V

COMPUTER MODELLING

5.1 Introduction

The results obtained using a computer model are described in this chapter. Also, a comparison between the results from field testing and model prediction is given.

The APF/Loads Model is a computer program written at the Oak Ridge National Laboratory (ORNL) for seasonal performance analysis of air-to-air heat pump systems (1). The model consists of two main parts. The APF portion requires an HVAC System Data file and a House Loads Data file as inputs and in turn generates an energy input breakdown along with a kilowatt allocation to the different loss mechanisms involved. These loss mechanisms include cycling, frosting, and defrosting for the heating mode and cycling for the cooling mode. The algorithms used by the APF/Loads Model to predict these dynamic losses are empirically based using test data from ORNL, National Bureau of Standards (NBS), and the Department of Energy (DOE) ratings test. The APF portion also gives the necessary runtimes involved to satisfy the given load conditions along with the required defrost time and strip heat usage for heating. This required defrost time can be computed for both timed and demand defrost systems and is again based on empirical data from ORNL, NBS, and DOE. Each of the heat pump system energy inputs predicted by the APF/Loads Model results along with each of the increases in

input due to the dynamic losses is given as a percentage of the total energy use for each season. The Loads portion can be used to generate a set of loads for a given house. The required input data files to generate this loads file are a HOUSE and a WEATHER data file. The HOUSE data file describes the construction details of the structure under consideration while the WEATHER data file describes the ambient conditions that the structure experiences. The Loads portion of the computer model can be bypassed by supplying the APF portion with measured load data which was the procedure used in this study.

The two HVAC System Data files used are given in Appendix B, Sections B.1 and B.2 on pages 138-139. Section B.1 contains the single-speed mode file while Section B.2 contains the dual-speed mode file. A detailed description of the basic requirements and options available with these files may be found in Reference 1 and will not be repeated here. However a few specific points will be made concerning these files. Line three of each file in Sections B.1 and B.2 contain the six program option switches. Table 5.1 gives the names of these option switches along with a general description and specific values used and their meaning for the single and dual-speed modes. Line five of each HVAC System Data file gives the ambient temperatures in °F for which heating data is given. The heating block of data is then given with line six of each file giving the modulation ratio (defined as actual compressor angular speed to maximum compressor angular speed) and line seven giving the compressor input in kilowatts. The next line gives the

Table 5.1 Program Option Switch Descriptions (1)

Name	Description and Specific Value Used and its Meaning
MTYINP	Type of principal energy input to HVAC equipment =1 for electric-driven
MCAPMD	Type of capacity modulation =1 for nonmodulating (single-speed mode) =3 for step-modulation with alternating between stops (dual-speed mode)
MPOWIN	Option to provide steady-state input energy or COP values =1 to specify energy input values (Kw)
MCYCLS	Type of cycling loss method =2 for the DOE "C _D " method
MFRSLS	Type of frosting/defrosting loss method =5 for use of ORNL experimental data-wavy fin
MTYDEF	Type of defrost cycle =1 for reversed cycle

heating capacities in kBtu/hr for each ambient temperature. Line nine gives the cyclic degradation factor obtained from the manufacturer along with on-time parasitic data. The next line gives frosting/defrosting information. Section B.2 contains an additional block of data for heating since it has two modulation ratios. It should be noted that both the single and dual-speed modes utilized a demand defrost model to better simulate the field operating characteristics. Following the heating data for each HVAC System Data file the cooling data are given. Both Sections B.1 and B.2 use manufacturer's heating capacities and field measured cooling capacities. The cooling capacities measured in this study were used

to better represent the attainable capacities since the manufacturer's values seemed to overestimate the actual values. Figure 5.1 shows the field cooling capacity values used along with the best fit straight line calculated for both low and high speed compressor operation. The field cooling capacities were found from the data given in Appendix A, Sections A.5 and A.6 on pages 102-103. The best fit straight lines were then used to obtain the cooling capacities at the desired ambient temperatures and these values appear in Sections B.1 and B.2. Also contained in the cooling data for each HVAC System Data file is the compressor input in kilowatts which appears on line 1 of the cooling block for each modulation ratio along with the cyclic degradation factor and on-time parasitic data given on line three for each modulation ratio.

The two House Load Data files used are given in Appendix B, Sections B.3 and B.4 on pages 140-147. Section B.3 contains the house loads when the heat pump was operating in the single-speed mode while Section B.4 contains the load file for dual-speed operation. Both follow a format described by the APF/Loads model and include heating and cooling load data in 5°F temperature bins for each month. The heating load data consist of daytime heating load, daytime hours, nighttime heating load, nighttime hours, and monthly mean coincidental wet bulb temperature for each temperature bin. The cooling load data consist of daytime total cooling load, daytime latent cooling load, daytime hours, nighttime total cooling load, nighttime latent cooling load, and nighttime hours for each

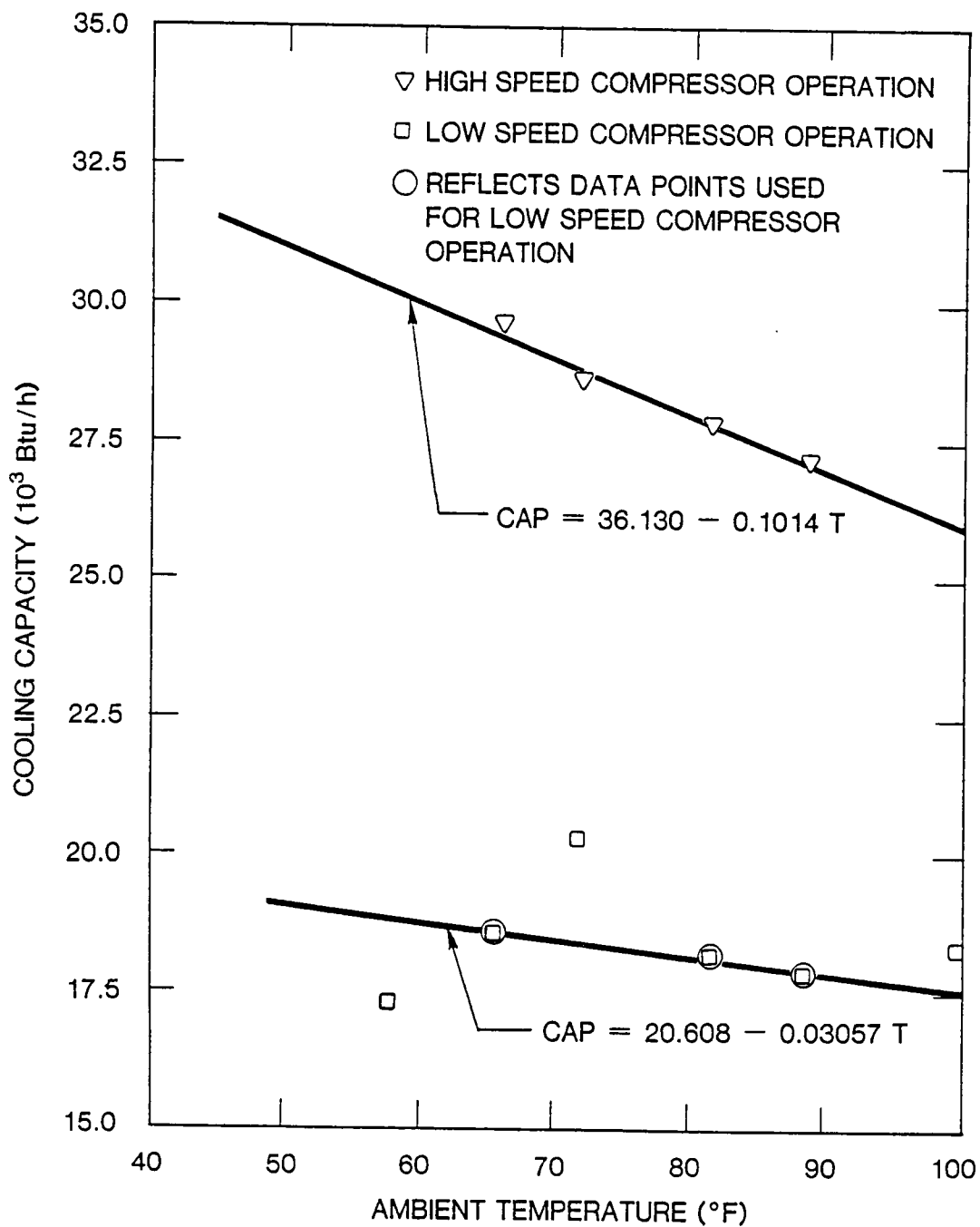


Figure 5.1 Field Measured Cooling Capacities for Low and High Speed Compressor Operation

temperature bin for each month. The load values are all in units of kBtu/hr. All of the load data, except for the mean coincidental wet bulb temperature, were obtained from the data recorded as described in Chapter 2. The mean coincidental wet bulb temperature was obtained by getting an average dry bulb temperature and relative humidity for each temperature bin for each month and then using Psychrometric charts to find the mean coincidental wet bulb temperature. In Appendix B, Sections B.5-B.7 on pages 148-156 give the computer programs used to obtain the house load data for the single and dual-speed modes of operation.

Modifications that were desirable when using the APF/Loads Model are now explained. The BLOCK subroutine which contained the record, or calender, of the number of data hours for each month was modified to agree with the single and dual-speed mode partial month data hours. Section B.8 in Appendix B on page 157 gives the single-speed mode BLOCK subroutine calender information while Section B.9 on page 157 gives the dual-speed mode BLOCK subroutine calender information. Also, for the dual-speed mode computer model runs it was desirable to change the method and temperature at which the model switched over from low to high speed compressor operation. This was done by modifying the SSTATE subroutine. A sample listing of the SSTATE subroutine used appears in Section B.10 of Appendix B on pages 158-159.

5.2 Results

In Appendix B, Section B.11 on pages 160-166 gives the output file obtained from the APF/Loads Model for the single-speed mode. For the dual-speed mode four different switch-over temperature (SOT) values were used for heating in the computer runs. These switch-over temperatures were 47°F, 42°F, 37°F, and 32°F, and were chosen to best simulate the controls discussed on the switch-over from low to high speed compressor operation for the field data. These switch-over temperatures chosen are also the midpoints of the 5°F temperature bins used by the APF/Loads Model and since the model refers all performance calculations to these midpoints the switch-over temperatures used by the dual-speed runs may be described as having a +2.5°F to -2.5°F dead band associated with them. Appendix B, Sections B.12-B.15 on pages 167-202 give the output files obtained from the computer model runs for the dual-speed mode. Section B.12 is for a switch-over temperature of 47°F while Sections B.13-B.15 give the results obtained for switch-over temperatures of 42°F, 37°F, and 32°F, respectively.

The basic format of the output obtained from the APF/Loads Model can be seen by referring to Sections B.11-B.15. The first item given is a summary of the heating performance data as specified in the HVAC System Data files. Included in this heating performance data is the steady-state data, cycling loss data, frost/defrost data, and on-time parasitic data. Following this information a summary of the cooling performance obtained from the HVAC System

Data file is given. Included in this cooling performance data is steady-state data, cycling loss data, and on-time parasitic data. Both the heating and cooling performance data are modulation ratio dependent and thus are given for the two dual-speed mode modulation ratios. Following the heating and cooling performance summaries the mode and modulation independent heat pump data are given. This includes the off-time parasitic data and whether or not the HVAC system was scaled on the model runs. Scaling of the model runs multiplies the heating and cooling capacities and power consumptions by a computed value allowing one to study the effect of changing the size of the heat pump system on the overall performance. A special note to be made is that both the single and dual-speed computer model runs utilized the DOE " C_D " method (10) for their cycling degradation losses and the off-time parasitic input was included in the values used and thus are not itemized separately. The next item given in the output files of Sections B.11-B.15 is the house, weather, and loads information. Following this are the performance calculations. The first performance calculations given are for heating. Using 5°F temperature bins along with day and night loads combined an itemized listing of hours in each bin, average load, COP's, capacities, percentage of on-time, and the inputs and outputs are given. Following this is a summary of the heating performance. Given in this summary are the seasonal input, output, and performance value, along with the hours of operation and defrost data. The energy inputs are then itemized along with a kilowatt-hour allocation given to the different loss mechanisms.

The percentages given to the right of these energy input values reflect the percentage of total energy use for the season that each term contributes. Following the heating season performance calculations the cooling season performance calculations are given. Again using 5°F temperature bins along with combined day and night loads an itemized listing of hours in each bin, average load, COP's, capacities, percentage of on-time, and the inputs and outputs are given. Following this is a summary of the cooling performance. Given in this summary are the seasonal input, output, and performance value. Next the cooling season energy use breakdown is given. This energy use breakdown gives the base total input along with the additional input due to the cycling losses. Each is given as a percentage of the total energy use. Following this is the annual performance summary which gives the annual input, output, and performance. Next an annual energy use breakdown is given. Included in this are the different inputs required along with their percentage of the the total energy use.

Table 5.2 summarizes the performance values obtained from the computer model runs for the single and dual-speed modes. As can be seen from this table the model always predicted higher performance for the dual-speed mode. Also, the HSPF's for the dual-speed mode increased as the switch-over temperature decreased.

Table 5.2 Performance Values Obtained from the
APF/Loads Model

Mode Description	Performance Values		
	HSPF	CSPF	APF
Single-Speed	2.00	1.85	1.94
Dual-Speed			
SOT=47°F	2.05	2.23	2.12
SOT=42°F	2.07	2.23	2.13
SOT=37°F	2.11	2.23	2.15
SOT=32°F	2.13	2.23	2.17

Table 5.3 summarizes the heating loss mechanism energy inputs and gives the percentage of base energy input total that each contributed for the single and dual-speed mode computer model runs. As can be seen from this table the amount of cycling loss input decreased as the switch-over temperature decreased for the dual-speed mode.

Table 5.3 Heating Loss Mechanism Energy Inputs and
Percentage of Total Summary

Mode Description	Loss Mechanism Input (kw-hr)		
	Back-Up Heat	Frosting/ Defrosting	Cycling
Single-Speed	162.4 (9.0%)	37.0 (2.0%)	117.9 (6.5%)
Dual-Speed SOT=47°F	111.0 (8.4%)	24.4 (1.8%)	114.4 (8.6%)
SOT=42°F	111.0 (8.4%)	24.4 (1.9%)	110.9 (8.4%)
SOT=37°F	111.0 (8.6%)	14.8 (1.1%)	100.9 (7.8%)
SOT=32°F	111.0 (8.7%)	19.2 (1.5%)	83.3 (6.5%)

Table 5.4 gives a summary of the type of hours that the dual-speed mode experienced during the heating season from the field results. This information came from Sections A.2-A.4 given in Appendix A on pages 102-104. As discussed in Chapter 3 there were four types of hours that the dual-speed mode could experience. Combined hours were all operating hours that the heat pump system experienced. Low hours were hours that the system operated in low compressor speed only for that hour. High hours were hours that the system operated in high compressor speed only for that hour. Low-high hours were hours that the system had where both low and high compressor speed was experienced for that hour. Based on the

type of hours given in Table 5.4 it is believed the APF/Loads Model runs using a switch-over temperature of 37°F for the dual-speed mode best simulated the field results even though the five low speed hours and two low-high hours given in the 23/32°F temperature bin cannot be accounted for.

Table 5.4 Types of Hours that the Dual-Speed Mode Experienced During the Heating Season

Bin Temperature	Combined Hours	Low Hours	High Hours	Low-High
15/20°C (59/68°F)	28	28 (100%)	0	0
10/15°C (50/59°F)	144	137 (95.1%)	3 (2.1%)	4 (2.8%)
5/10°C (41/50°F)	227	202 (89.0%)	17 (7.5%)	8 (3.5%)
0/5°C (32/41°F)	233	89 (38.2%)	127 (54.5%)	17 (7.3%)
-5/0°F (23/32°F)	145	5 (3.4%)	138 (95.2%)	2 (1.4%)
-10/-5°C (14/23°F)	46	0	46 (100%)	0

Figure 5.2 compares the overall heating COP's obtained from the APF/Loads Model runs for the single and dual-speed modes. Noting that this overall COP given by the APF/Loads Model for the individual temperature bins does not include back-up strip heat or

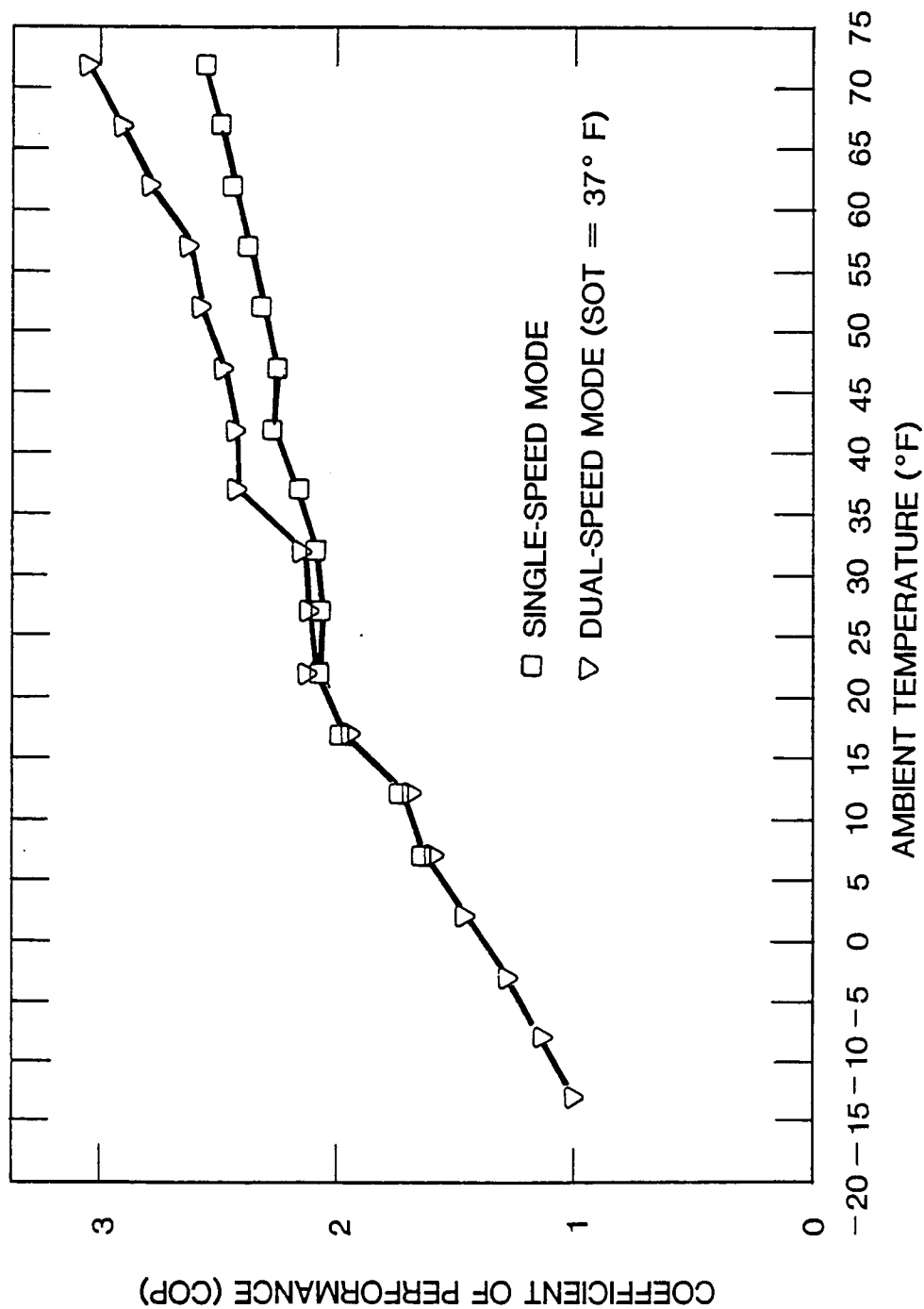


Figure 5.2 Comparison of Predicted Overall Heating APF/Loads Model COP's for the Single and Dual-Speed Modes

normal I²r ones sees that the overall COP's for the single and dual-speed modes are essentially equal until the switch-over temperature of 37°F is reached. In this switch-over temperature bin the dual-speed mode begins to operate in low compressor speed for these lighter heating load conditions and thus the dual-speed mode is seen to have a higher overall COP than the single-speed mode. Because of this the dual-speed mode is seen to have a higher HSPF than the single-speed mode, 2.11 compared to 2.00 as given in Table 5.2.

Table 5.5 summarizes the cooling cycling loss energy input and its percentage of the base energy input total for the single and dual-speed modes. Since the change in switch-over temperature for the dual-speed mode pertained only to heating all four output files had the same cooling performance values. As seen from Table 5.4 the dual-speed mode had a lower cycling loss energy input than the single-speed mode.

Table 5.5 Cooling Cycling Loss Energy Input and
Percentage of Total Summary

Mode Description	Cycling Loss Input (Kw-hr)
Single-Speed	98.9 (8.7%)
Dual-Speed	56.4 (7.0%)

Figure 5.3 compares the overall cooling COP's obtained from the APF/Loads Model runs for the single and dual-speed modes based on their site weather conditions. From this figure it is seen that the overall COP of the dual-speed mode is greater than the overall COP for the single-speed mode for all temperature bins. Noting that the dual-speed mode switch-over for cooling was based on whether the heat pump system could or could not meet its cooling load and observing the cooling capacity versus cooling load information given in Tables B.12-B.15 one notes that the dual-speed always operated in low compressor speed during the cooling season. This contributed to the CSPF of the dual-speed mode being higher than that of the single-speed mode, 2.23 compared to 1.85 as given in Table 5.2.

Annual energy use breakdowns are given in Appendix B, Tables B.11-B.15, and the annual performance values obtained from the APF/Loads model are given in Table 5.2.

To get an idea of the performance of the single-speed mode compared to the dual-speed mode an additional computer run was made using the same weather conditions. In this run the single-speed mode HVAC System Data file given in Section B.1 on page 138 was used along with dual-speed mode Load Data file given in Section B.4 on pages 144-147. It was also necessary to use the dual-speed mode BLOCK subroutine calendar information given in Section B.9 on page 157 so that the number of load hours agreed with the number of calendar hours. The results obtained from this APF/Loads model run are given in Section B.16 on pages 203-209. The performance values

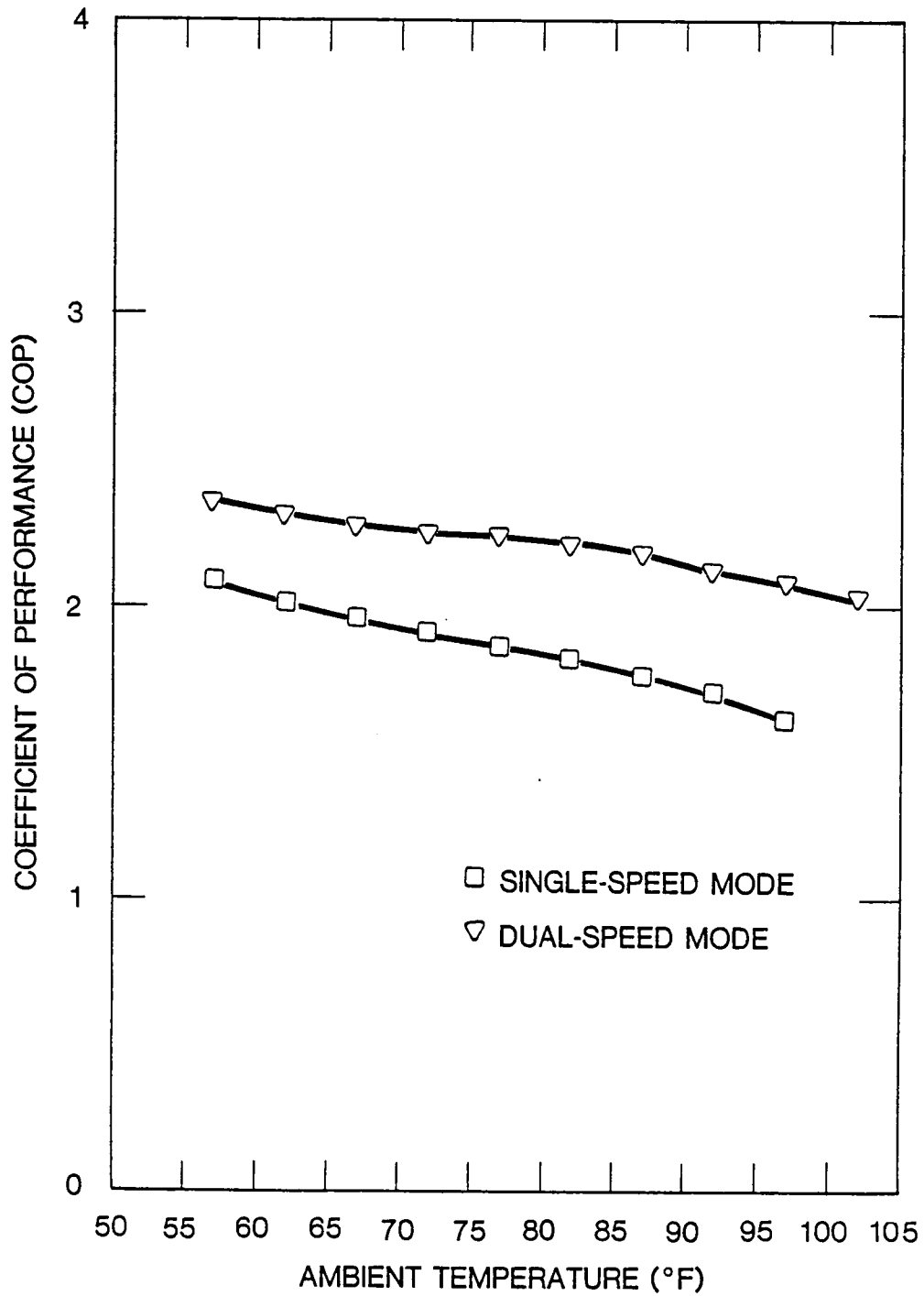


Figure 5.3 Comparison of Predicted Overall Cooling APF/Loads Model COP's for the Single and Dual-Speed Modes

obtained were found to be 2.03 for the HSPF, 1.85 for the CSPF, and 1.95 for the APF. Thus, comparing the APF/Loads Model performance value results for the single and dual-speed modes under identical load conditions one finds that the dual-speed mode HSPF of 2.11 was only slightly higher than the single-speed mode HSPF (2.03), the dual-speed mode CSPF of 2.23 was higher than the single-speed mode CSPF (1.85), and the dual-speed mode APF of 2.15 was higher than the single-speed mode APF (1.95).

Figure 5.4 compares the overall heating COP's obtained from the APF/Loads Model runs for the single and dual-speed modes under the same heating load conditions. Being very similar to the results given in Figure 5.2, Figure 5.4 shows the COP values to be identical until the switch-over temperature of 37°F is reached, after which the dual-speed mode has a higher overall COP than the single-speed mode. This is again due to the dual-speed mode switching to low compressor speed which contributes to the difference in HSPF values for the single and dual-speed modes under identical load conditions.

Figure 5.5 compares the overall cooling COP's obtained from the APF/Loads Model runs for the single and dual-speed modes under the same cooling load conditions. This figure shows like Figure 5.3 showed that the overall COP of the dual-speed mode was always higher than the overall COP of the single-speed mode.

The heating loss mechanism input values given in Section B.16 of 110.2 Kw-hr for normal I²r, 24.4 Kw-hr for frosting/defrosting, and 116.3 Kw-hr for cycling are very close to the dual-speed's heating loss mechanism input values. Thus, as mentioned before the

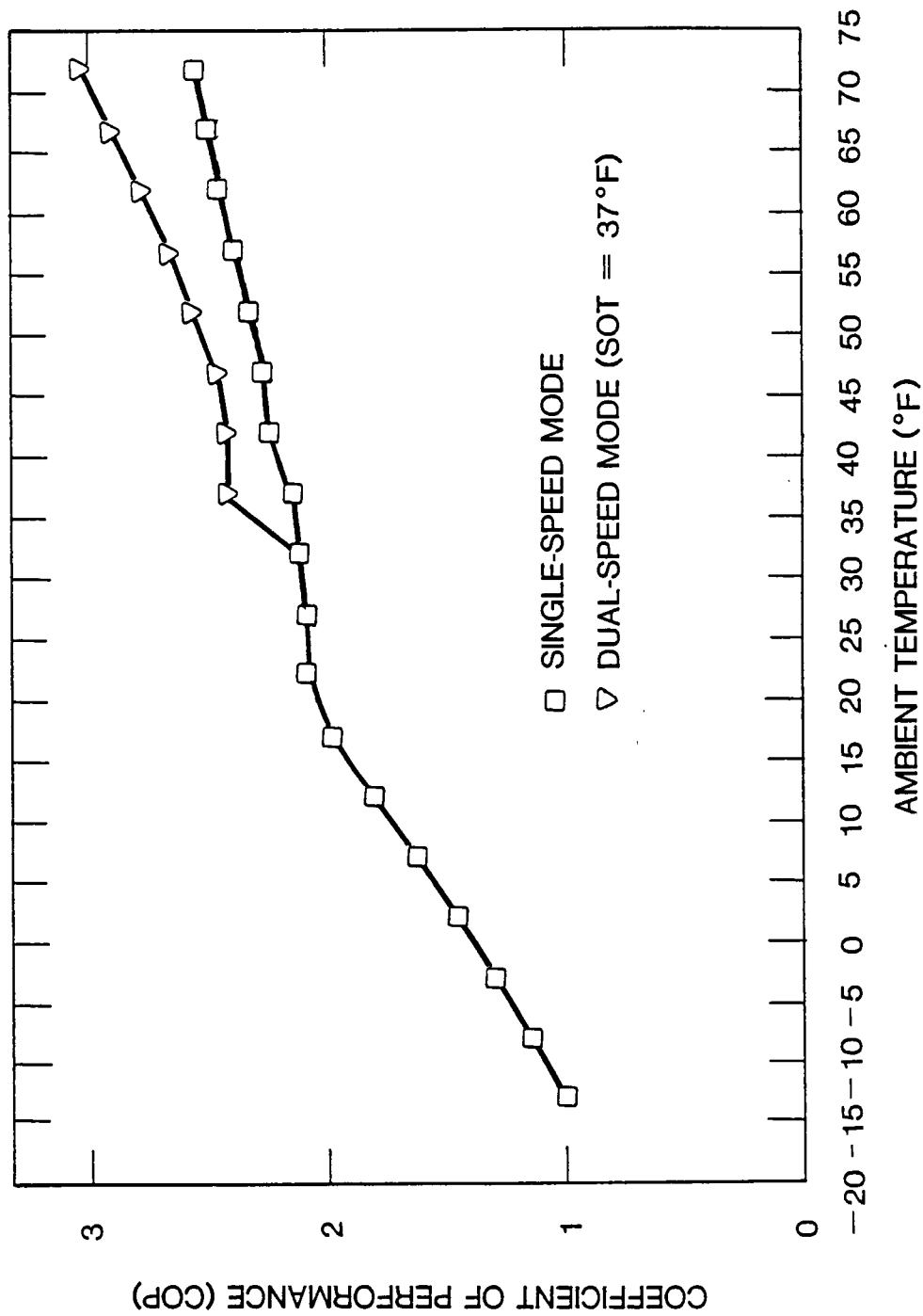


Figure 5.4 Comparison of Predicted Overall Heating APF/Loads Model COP's for the Single and Dual-Speed Modes Under the Same Load Conditions

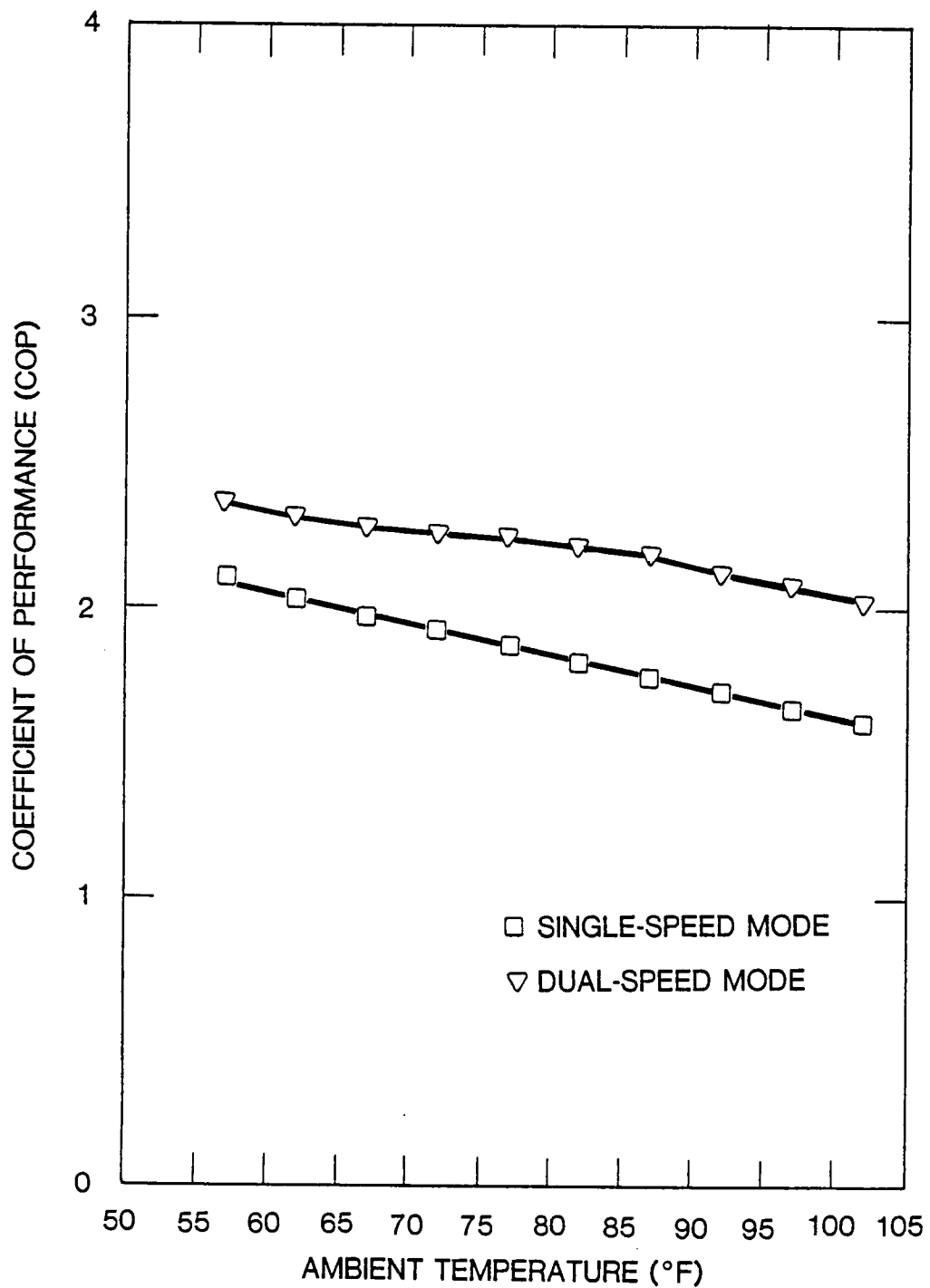


Figure 5.5 Comparison of Predicted Overall Cooling APF/Loads Model COP's for the Single and Dual-Speed Modes Under the Same Load Conditions

HSPF for the single and dual-speed modes under identical load conditions agree very closely. This difference in HSPF for the two modes increases as the SOT decreases for the dual-speed mode. The cooling cycling loss mechanism input value given in Section B.16 of 88.3 Kw-hr is higher than the dual-speed mode value of 56.4 Kw-hr. Thus cycling occurred more often with the single-speed mode during the cooling season and contributed to the single-speed mode CSPF being less than the dual-speed mode CSPF.

5.3 Comparison of the APF/Loads Model Results to the Field Results

Table 5.6 shows a summary of the APF/Loads Model and field performance values along with a percent error between the two. Based on the results given in this table it can be concluded that the dual-speed mode performance predicted by the APF/Loads Model was closer to the field performance values than the single-speed mode. This difference in heating and annual performance values is even less when the APF/Loads Model results for a switch-over temperature of 32°F are used even though as presented previously, it is believed that the use of a switch-over temperature of 37°F for the dual-speed mode best simulates the field data.

Table 5.6 Performance Values Comparison Summary for the Single and Dual-Speed Modes

Mode Description	HSPF	CSPF	APF
Single-Speed Mode (field results)	2.11	2.09	2.10
Single-Speed Mode (APF Model results)	2.00	1.85	1.94
% Difference	5.21	11.5	7.62
Dual-Speed Mode (field results)	2.17	2.27	2.20
Dual-Speed Mode (APF Model results)	2.11	2.23	2.15
% Difference	2.78	1.76	2.33

Figure 5.6 compares the overall APF/Loads Model and field heating COP's for the Single-Speed Mode. The APF/Loads Model overall COP is seen to agree with the field overall COP except for the two warmer temperature bins of the field results where off-cycle crankcase energy input was dominant. Since the cyclic degradation factor used by the APF/Loads Model for these computer runs included the effect of the off-cycle crankcase energy input, the model tended to spread this effect out over all involved temperature bins and not account for all of the crankcase input in the warmer or lighter heating load temperature bins. This led to the overall COP of the APF/Loads Model results be consistently less than the field overall COP for the majority of the bins involved and being much greater for

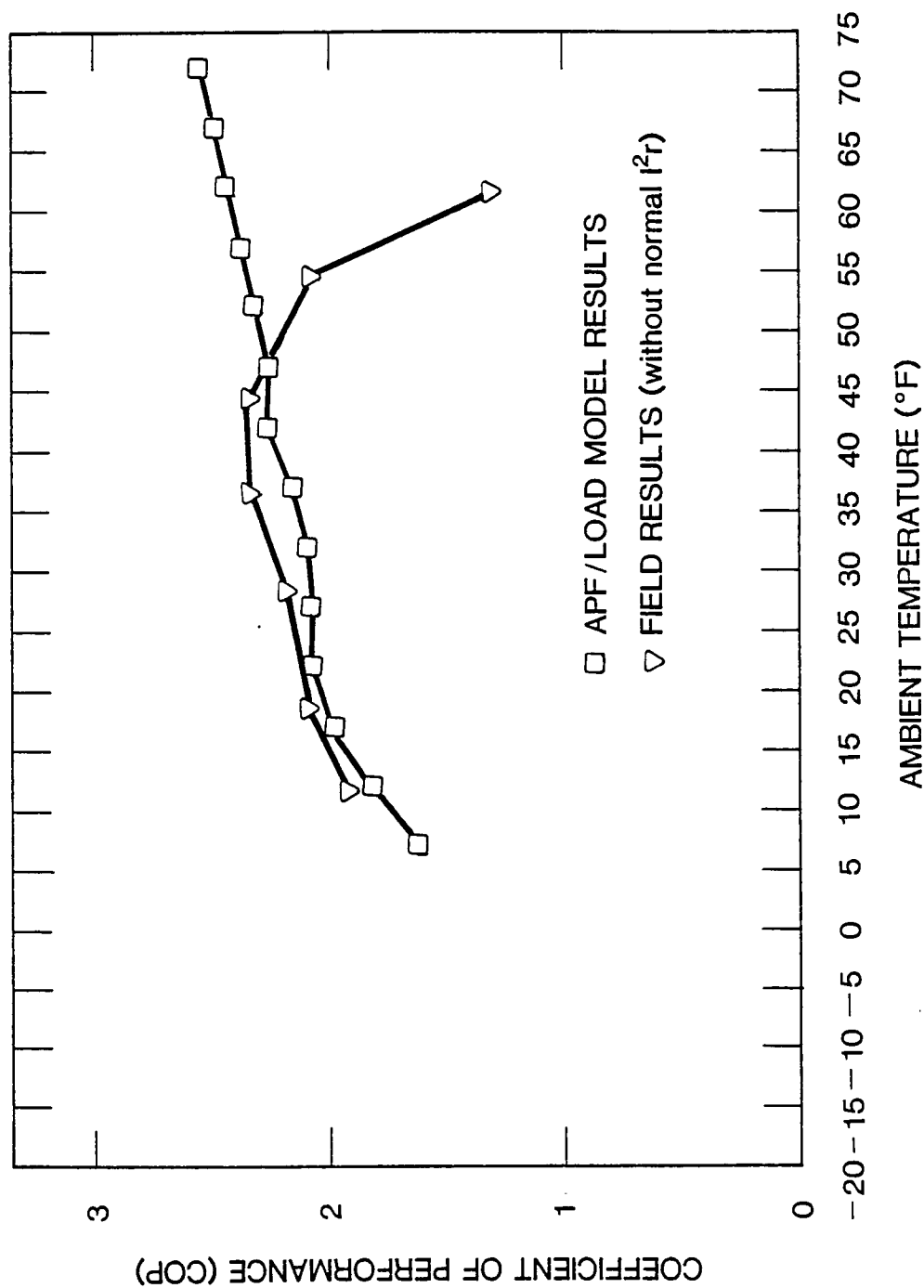


Figure 5.6 Comparison of Overall APF/Loads Model and Field Heating COP's for the Single-Speed Mode

the warmer temperature bins. Due to the % error between the APF/Loads Model and field overall heating COP's being only 5.21% this indicates an acceptable treatment of this off-cycle crankcase energy input.

Figure 5.7 is the corresponding comparison for the overall COP's for the dual-speed mode. This comparison tends to show more of a cross over between the APF/Loads Model and field overall COP's in the middle temperature bins than the single-speed mode. Again, the warmer temperature bins show a greater spread due to the off-cycle crankcase energy input being dominant in these bins for the field results.

Table 5.7 compares the APF/Loads Model heating loss mechanism input values and percentage of total summary to the field values for the single and dual-speed modes. The percentages given for the frosting/defrosting and cycling losses for the field results are based on COPN for both the single and dual-speed modes while the percentages given for the frosting/defrosting and cycling losses for the APF/Loads Model results have been adjusted to be exclusive of normal I^2R for comparison sake to the field results. For both modes of operation it is seen that the APF/Loads Model overestimated the back-up heat required, underestimated the frosting/defrosting losses, and overestimated the cycling losses.

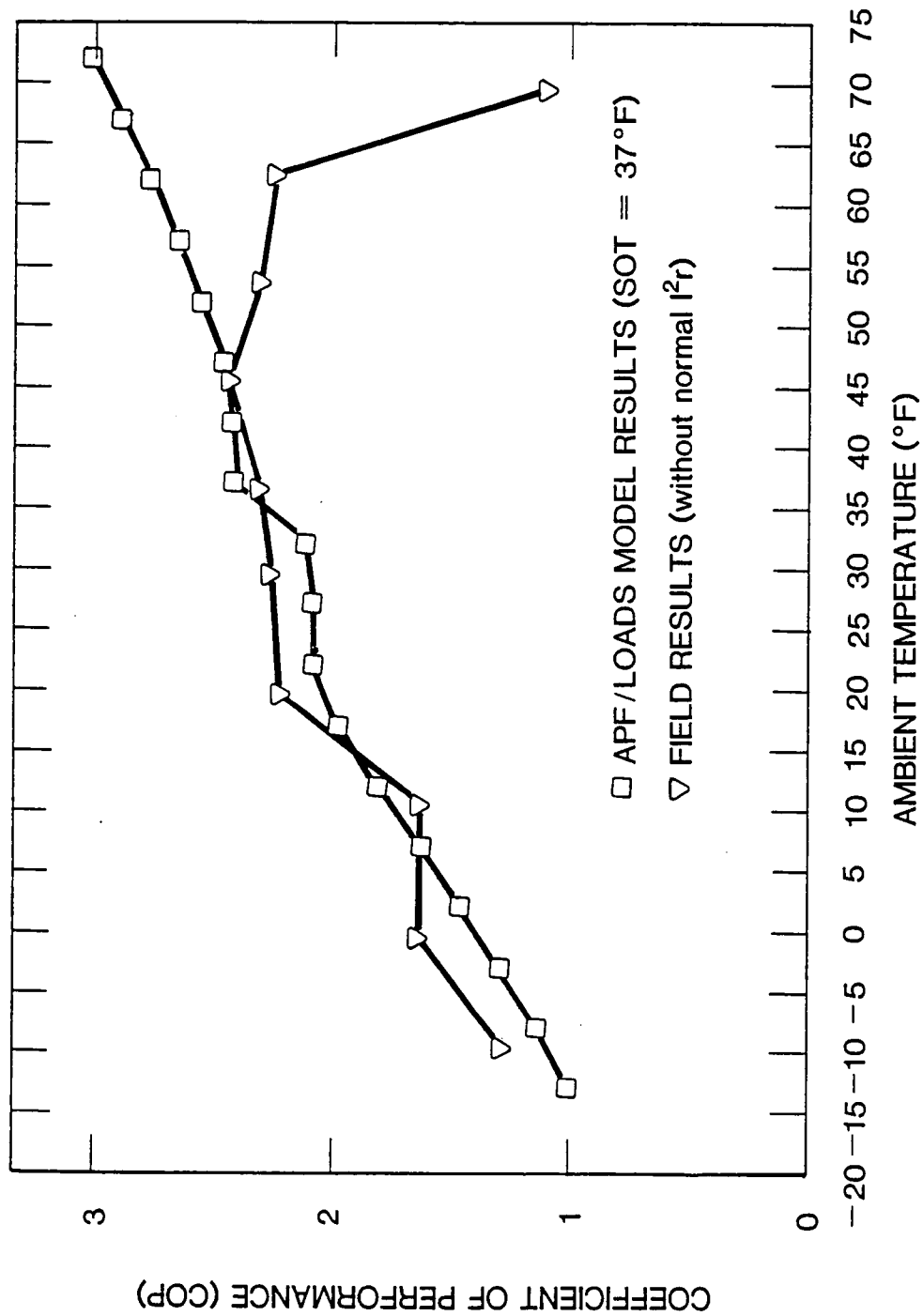


Figure 5.7 Comparison of Overall APF/Loads Model and Field Heating COP's for the Dual-Speed Mode

Table 5.7 Comparison of the APF/Loads Model and Field Heating Loss Mechanism Inputs and Percentage of Total Summary for the Single and Dual-Speed Modes

Mode Description	Loss Mechanism Input (kw-hr)		
	Back-up Heat	Frosting/ Defrosting	Cycling
Single-Speed Mode (field results)	118.2 (6.9%)	62.8 (3.9%)	76.3 (4.7%)
Single-Speed Mode (APF Model results)	162.4 (9.0%)	37.0 (2.8%)	117.9 (8.8%)
Dual-Speed Mode (field results)	89.9 (7.2%)	64.3 (5.5%)	75.8 (6.5%)
Dual-Speed Mode (APF Model results for SOT=37°F)	111.0 (8.6%)	14.8 (1.2%)	100.9 (8.5%)

Table 5.8 compares the APF/Loads Model defrost data to the field defrost data for the single and dual-speed modes. The defrost data of the single-speed mode is seen to show fairly good agreement. The defrost data of the dual-speed mode however shows the APF/Loads Model to have grossly underestimated all of the defrost data values.

Table 5.8 Comparison of the APF/Loads Model and Field Defrost Data for the Single and Dual-Speed Modes

Mode Description	Defrost Data			
	Operating Time (hrs)	# of Cycles	HP Input (Kw-hr)	Strip Heat Input (Kw-hr)
Single-Speed Mode (field results)	3.8	41	13.5	42.7
Single-Speed Mode (APF Model results)	4.9	50.5	11.6	49.0
Dual-Speed Mode (field results)	4.7	42	13.6	45.2
Single-Speed Mode (APF Model results for SOT=37°F)	2.1	22.3	4.9	20.7

Figure 5.8 compares the overall APF/Loads Model and field cooling COP's for the single-speed mode. Figure 5.9 is the corresponding dual-speed mode comparison. Figure 5.8 shows the APF/Loads Model to have underestimated the overall COP for the single-speed mode for all temperature bins. This led to the APF/Loads Model CSPF value of 1.85 being lower than the field CSPF value of 2.09. Figure 5.9 shows good agreement between the APF/Loads Model and field overall COP's for the middle temperature bins but shows a great difference for the cooler or lighter cooling load conditions. This is again due to the way the off-cycle crankcase energy input dominates the field input in these lower cooling load conditions and the fact that the APF/Loads Model tends

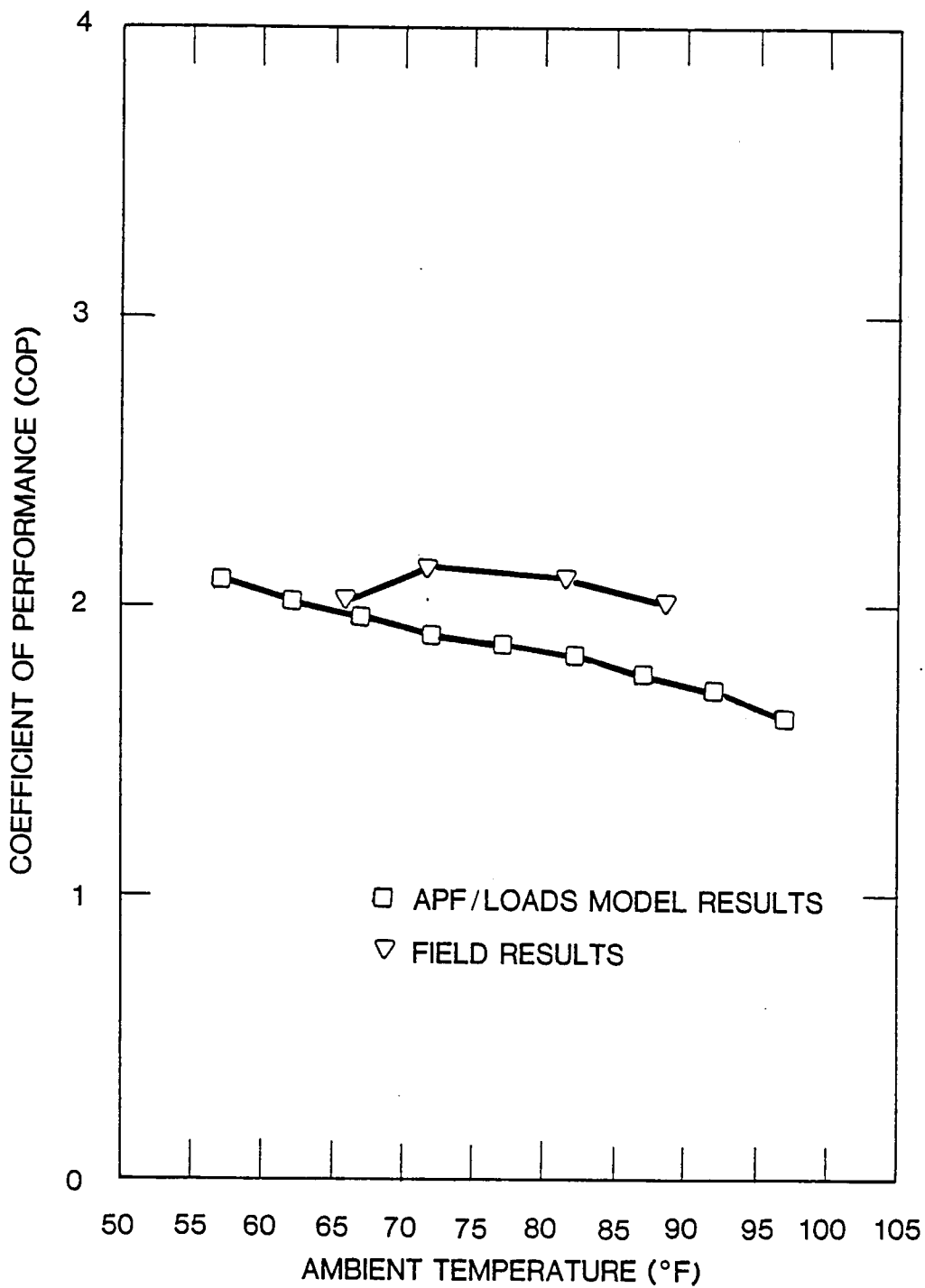


Figure 5.8 Comparison of Overall APF/Loads Model and Field Cooling COP's for the Single-Speed Mode

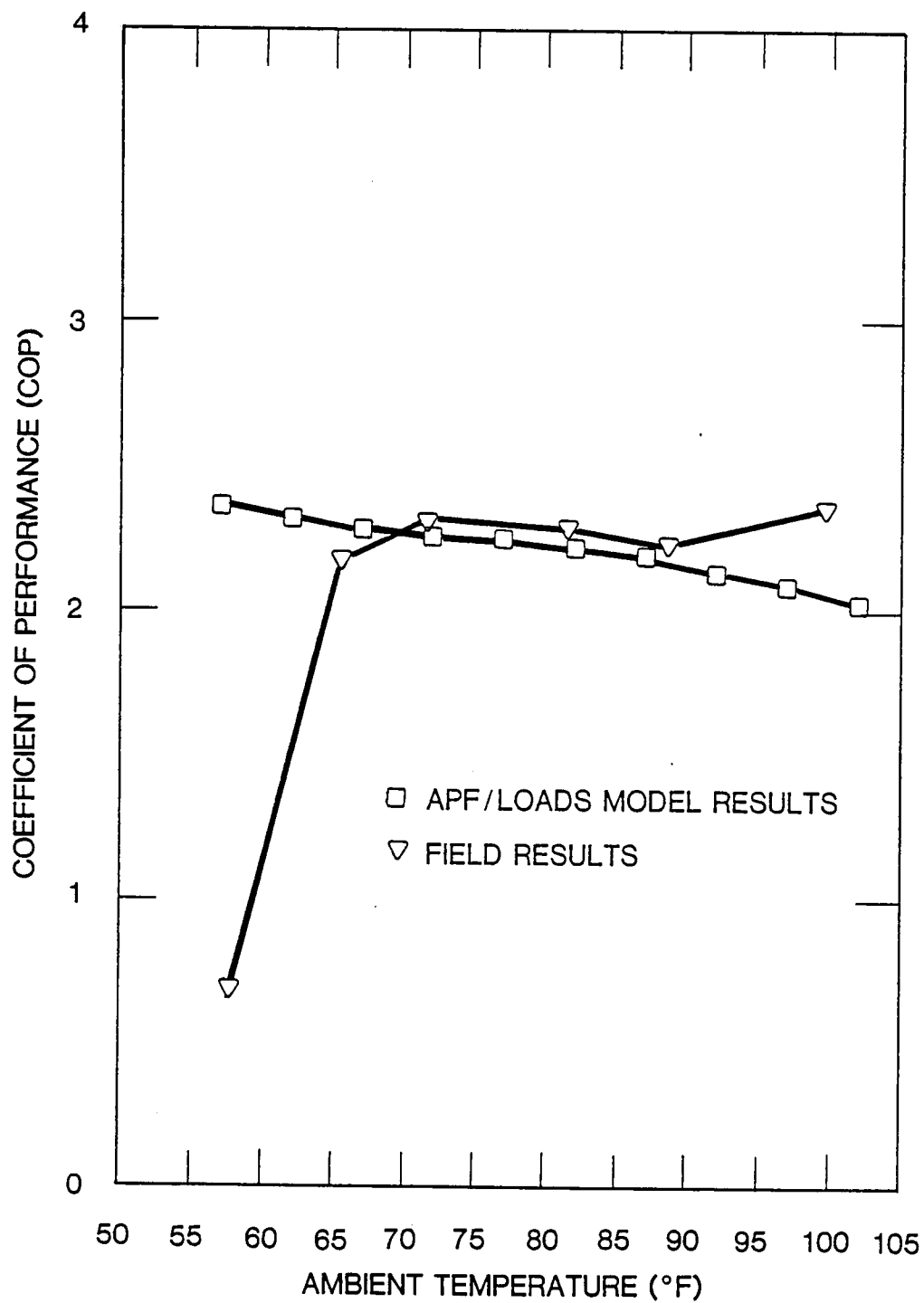


Figure 5.9 Comparison of Overall APF/Loads Model and Field Cooling COP's for the Dual-Speed Mode

to account for the off-cycle crankcase energy input in more temperature bins when the DOE "C_D" method is used.

Table 5.9 compares the APF/Loads Model and field cooling cycling loss energy input for the single and dual-speed modes. Also given is their percentage of total. As with heating the model is seen to have overpredicted the cycling loss input for the single and dual-speed modes during the cooling season. This contributed to the CSPF values predicted by the APF/Loads Model to be less than the field CSPF values.

Table 5.9 Comparison of the APF/Loads Model and Field Cooling Cycling Loss Energy Input and Percentage of Total
Summary for the Single and Dual-Speed Modes

Mode Description	Cycling Loss Input (Kw-hr)
Single-Speed Mode (field results)	60.3 (6.0%)
Single-Speed Mode (APF Model results)	98.9 (8.7%)
Dual-Speed Mode (field results)	34.0 (4.3%)
Dual-Speed Mode (APF Model results)	56.4 (7.0%)

Because of the overestimation of the cycling loss input for both heating and cooling by the APF/Loads Model additional computer runs were done for the single and dual-speed modes. These additional runs used field " C_D " values that were calculated using a procedure outlined in Reference 10. The field heating " C_D " values calculated were 0.12 for high speed compressor operation and 0.16 for low speed compressor operation. The previously used heating " C_D " values which were supplied by the manufacturer were 0.20 for high speed compressor operation and 0.22 for low speed compressor operation. The field cooling " C_D " values calculated were 0.11 for high speed compressor operation and 0.14 for low speed compressor operation. The previously used cooling " C_D " values which were supplied by the manufacturer were 0.13 for high speed compressor operation and 0.13 for low speed compressor operation. These field " C_D " values for both heating and cooling were substituted for the manufacturer " C_D " values given in Sections B.1 and B.2 of Appendix B on pages 138-139. The APF/Loads Model was then run with these HVAC System Data files.

Table 5.10 shows a comparison of the new heating parameter values obtained from the APF/Loads Model using the field " C_D " values to the field results. The cycling loss input values given by the APF/Loads Model and field results are seen to show much better agreement than previously calculated values. The HSPF values are also seen to show much better agreement.

Table 5.10 Comparison of the APF/Loads Model and Field Heating Parameters with Adjusted " C_D " Values

Mode Description	Frosting/ Defrosting Losses (Kw-hr)	Cycling Losses (Kw-hr)	HSPF
Single-Speed Mode (field results)	62.8 (3.9%)	76.3 (4.7%)	2.11
Single-Speed Mode (APF Model results)	34.4 (2.2%)	67.3 (4.2%)	2.06
Dual-Speed Mode (field results)	64.3 (5.5%)	75.8 (6.5%)	2.17
Dual-Speed Mode (APF Model results for SOT=37°)	13.7 (1.1%)	66.0 (5.7%)	2.17

Table 5.11 shows a comparison of the new cooling parameter values obtained from the APF/Loads Model using the field " C_D " values to the field results. The cycling loss input values given by the APF/Loads Model and field results for the single-speed mode are seen to show better agreement while the dual-speed mode's cycling loss values show a little less agreement. Consequently, the CSPF values for the single-speed mode are closer while the CSPF values for the dual-speed mode show a greater difference.

Table 5.11 Comparison of the APF/Loads Model and Field Cooling Parameters with Adjusted "C_D" Values

Mode Description	Cycling Losses (Kw-hr)	CSPF
Single-Speed Mode (field results)	60.3 (6.0%)	2.09
Single-Speed Mode (APF Model results)	82.4 (7.4%)	1.99
Dual-Speed Mode (field results)	34.0 (4.3%)	2.27
Dual-Speed Mode (APF Model results)	61.2 (7.5%)	2.19

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

6.1 Heating Season Conclusions

Based on the heating season performance results the following conclusions can be made:

1. The dual-speed mode's HSPF of 2.17 was higher than the single-speed mode's HSPF of 2.11.

2. The manufacturer's steady-state capacities and the normal capacities showed good agreement for both low and high speed compressor operation.

3. The defrost stage degraded the overall performance for both the single and dual-speed mode. However, the demand defrost gave a lower % time defrost than the timer defrost used in Reference 10 and thus offers a potential Kw-hr savings.

Due to the range of heating load conditions at which the heat pump system switched from low to high speed compressor operation, it is felt that the control system involved was not effective enough in offering the potential enhancements of the dual-speed mode. The fact that the thermostat used to control this switch-over had a +6°F to -6°F dead band along with the system having to run until it met the heating load before it could switch-over contributed greatly to the performance results not showing as much of a difference as one would expect during the heating season.

6.2 Cooling Season Conclusions

Based on the cooling season performance results the following conclusions can be made:

1. The dual-speed mode's CSPF of 2.27 was higher than the single-speed mode's CSPF of 2.09.
2. The dual-speed mode ran almost entirely in low speed compressor operation.
3. The manufacturer's steady-state cooling capacities tended to overestimate the measured field cooling capacity values for both low and high speed compressor operation.
4. The sensible heat ratio values of the dual-speed mode were always higher than those of the single-speed mode. Thus the single-speed mode was more effective at reducing the humidity of the indoor air.

The switch-over from low to high speed compressor operation during the cooling season was probably controlled adequately. However, because the heat pump system operated only 3.353 hours or 0.97% of its operating time in high speed compressor operation during the dual-speed mode it is felt that the system may have been slightly oversized for cooling purposes.

6.3 Computer Model Analyses Conclusions

Based on the results given by the APF/Loads Model the following conclusions can be made:

1. The single-speed mode HSPF value of 2.00 given by the model was 5.21% lower than the field value of 2.11 while the dual-speed mode's HSPF of 2.05-2.13 given by the model was 5.53-1.84% lower than the field value of 2.17.

2. The single-speed mode's CSPF of 1.85 given by the model was 11.5% lower than the field value of 2.09 while the dual-speed mode's CSPF of 2.23 given by the model was 1.76% lower than the field value of 2.27.

3. Annual performance values predicted by the APF/Loads Model of 1.94 for the single-speed mode and 2.12-2.17 for the dual-speed mode were 7.62% lower for the single-speed mode and 3.64-1.36% low for the dual-speed mode.

4. The HSPF values predicted by the APF/Loads Model increase as the switch-over temperature decreases. These HSPF values also show better agreement with the field results as the switch-over temperature decreases even though a switch-over temperature of 37°F best simulates the field data.

5. The back-up heat predicted by the APF/Loads Model of 162.4 Kw-hr (9.0% of the total input) for the single-speed mode and 111.0 Kw-hr (8.6% of the total input) for the dual-speed mode (SOT=37°F) was higher than the field values of 118.2 Kw-hr (6.9% of the total input) for the single-speed mode and 89.9 Kw-hr (7.2% of the total input) for the dual-speed mode.

6. The frosting/defrosting degradation factors of 2.8% for the single-speed mode and 1.2% for the dual-speed mode (SOT=37°F)

predicted by the APF/Loads Model were lower than the field values of 3.9% for the single-speed mode and 5.5% for the dual-speed mode.

7. The heating cycling degradation factors of 8.8% for the single-speed mode and 8.5% for the dual-speed mode (SOT=37°F) predicted by the APF/Loads Model are higher than the field values of 4.7% for the single-speed mode and 6.5% for the dual-speed mode.

8. The cooling cycling degradation factors of 8.7% for the single-speed mode and 7.0% for the dual-speed mode are higher than the field values of 2.7% and 1.0% for the single and dual-speed modes.

6.4 Recommendations

The main recommendation to be made is to perform further laboratory investigations where the conditions can be more closely controlled and where more data hours can be used to evaluate the performance and degradation factors for the single and dual-speed modes of a test heat pump under the same load conditions. Also, the ability to better identify the advantages and/or disadvantages of the dual-speed mode should be attainable in this study. It is recommended that the +6°F to -6°F dead band involved on the switch-over from low to high speed compressor operation for the dual-speed mode be reduced to improve performance. Also, it is recommended that the heat pump system not have to meet the heating load and experience normal shut-off before switching over during the dual-speed mode of operation.

LIST OF REFERENCES

1. Rice, C.K., Fischer, S.K., Emerson, C.J., The Oak Ridge Heat Pump Models: II. An Annual Performance Factor/Loads Model for Residential Air-Source Heat Pumps, ORNL/CON-160, Volumes 1 and 2, Oak Ridge National Laboratory, Oak Ridge, Tennessee, to be published.
2. Reay, D.A. and MacMichael, D.B.A., Heat Pumps Design and Applications, 1979, Pergamon Press.
3. Sauer, H.J., Jr. and Howell, R.H., Heat Pump Systems, 1983, John Wiley & Sons.
4. Muir, E.B. and Griffith, R.W., "Capacity Modulation for Air Conditioning and Refrigeration Systems," Air Conditioning News.
5. Cawley, R.E., "Two-speed Compressors In Heat Pumps," 11th Energy Conference, March 19-21, 1984.
6. Holman, A.S. and Abbatiello, L.A., Annual Cycle Energy System (ACES) Performance Report November 1977 through September 1978, ORNL/CON-42, Oak Ridge National Laboratory, Oak Ridge, Tennessee, May 1980.
7. Baxter, V.D., ACES Final Performance Report, December 1, 1978 through September 15, 1980, ORNL/CON-64, Oak Ridge National Laboratory, Oak Ridge, Tennessee, April 1981.
8. Bledsoe, J.L. and Miller, D.R., Data Collection and Processing for the ACES, ORNL/CON-59, Oak Ridge National Laboratory, Oak Ridge, Tennessee, November 1981.
9. McGraw, B.A. and Miller, D.R., "Successful Instrumentation Techniques Developed for the TECH Facility," pp. 244-249 in Solar Engineering-1983: Proceedings of the Fifth Annual Technical Conference of the ASME Solar Energy Division, Orlando, Florida, April 18-21, 1983, American Society of Mechanical Engineers, New York, 1983.
10. Baxter, V.D. and Moyers, J.C., Air-Source Heat Pump: Field Measurement of Cycling, Frosting and Defrosting Losses, 1981-83, ORNL/CON-150, Oak Ridge National Laboratory, Oak Ridge, Tennessee, November 1984.
11. Holman, J.P., Experimental Methods for Engineers, 1978, McGraw-Hill.

APPENDIXES

APPENDIX A

A.1 Single-Speed Mode Heating Bin Data Results

	-25/-20	-20/-15	-15/-10	-10/-5	-5/0	0/5	5/10	10/15	15/20	20/25	25/30
AVERAGE BIN TEMPERATURE (C)	0.000	0.000	-11.292	-7.679	-2.166	2.575	6.746	12.505	16.403	20.845	0.000
AVERAGE BIN REL. HUMIDITY (%)	0.000	0.000	67.111	60.021	56.906	58.240	48.143	42.089	31.000	35.138	0.000
# OF HOURS IN BIN	0.000	0.000	38.000	96.000	248.000	313.000	81.000	34.000	13.000	4.000	0.000
TRANSIENT OPERATING TIME (HR)	0.000	0.000	0.067	1.867	31.200	46.000	9.800	3.200	1.000	0.267	0.000
NORMAL OPERATING TIME (HR)	0.000	0.000	38.178	90.958	132.870	92.094	13.419	3.179	0.795	0.110	0.000
DEFROST OPERATING TIME (HR)	0.000	0.000	0.192	0.598	2.061	0.953	0.000	0.000	0.000	0.000	0.000
# OF START-UP CYCLES	0.000	0.000	1.000	28.000	468.000	690.000	147.000	48.000	15.000	4.000	0.000
# OF DEFROST CYCLES	0.000	0.000	2.000	6.000	22.000	11.000	0.000	0.000	0.000	0.000	0.000
TRANSIENT INPUT ENERGY (KW-HR)	0.000	0.000	0.197	5.684	101.485	153.043	33.816	10.918	3.261	0.802	0.000
NORMAL INPUT ENERGY (KW-HR)	0.000	0.000	110.741	275.737	427.605	323.908	48.742	12.686	3.547	0.777	0.000
DEFROST INPUT ENERGY (KW-HR)	0.000	0.000	0.650	2.034	7.412	3.419	0.000	0.000	0.000	0.000	0.000
TOTAL CRANKCASE INPUT (KW-HR)	0.000	0.042	0.000	0.110	3.488	7.461	4.726	4.912	6.669	2.891	0.381
TOTAL ENERGY INPUT (KW-HR)	0.000	0.042	111.588	283.565	539.990	487.831	87.284	28.516	13.476	4.470	0.381
TRANSIENT OUTPUT ENERGY (KW-HR)	0.000	0.000	0.388	11.965	222.125	346.971	77.243	25.139	7.653	1.892	0.000
NORMAL OUTPUT ENERGY (KW-HR)	0.000	0.000	285.304	636.731	999.011	814.014	127.223	34.279	9.895	2.321	0.000
DEFROST OUTPUT ENERGY (KW-HR)	0.000	0.000	1.183	3.234	11.445	5.662	0.000	0.000	0.000	0.000	0.000
TOTAL OUTPUT ENERGY (KW-HR)	0.000	0.000	286.875	651.931	1232.581	1166.647	204.465	59.418	17.548	4.212	0.000
NORMAL STRIP HEAT (KW-HR)	0.000	0.000	67.689	46.244	4.265	0.000	0.000	0.000	0.000	0.000	0.000
DEFROST STRIP HEAT (KW-HR)	0.000	0.000	2.484	6.678	22.940	10.563	0.000	0.000	0.000	0.000	0.000
TRANSIENT COP	0.000	0.000	1.967	2.105	2.189	2.267	2.284	2.303	2.347	2.357	0.000
NORMAL COP (WITHOUT STRIP)	0.000	0.000	1.965	2.141	2.326	2.513	2.610	2.702	2.790	2.987	0.000
TR+NOR COP (WITHOUT STRIP)	0.000	0.000	1.965	2.140	2.285	2.397	2.343	2.084	1.302	0.942	0.000
NORMAL COP (WITH STRIP)	0.000	0.000	1.599	1.978	2.313	2.513	2.610	2.702	2.790	2.987	0.000
DEFROST COP (WITH STRIP)	0.000	0.000	0.377	0.371	0.377	0.405	0.000	0.000	0.000	0.000	0.000
OVERALL COP	0.000	0.000	1.578	1.937	2.173	2.341	2.343	2.084	1.302	0.942	0.000
# OF LOW SPEED CYCLES	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
# OF HIGH SPEED CYCLES	0.000	0.000	1.000	28.000	468.000	690.000	147.000	48.000	15.000	4.000	0.000
LOW SPEED STRIP HEAT (KW-HR)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
% TIME IN DEFROST	0.000	0.000	0.499	0.640	1.240	0.685	0.000	0.000	0.000	0.000	0.000
% TIME IN TRANSIENT	0.000	0.000	0.173	1.998	18.780	33.082	42.207	50.163	55.702	70.796	0.000
OVERALL COP (WITHOUT NOR STRIP)	0.000	0.000	1.921	2.087	2.182	2.341	2.343	2.084	1.302	0.942	0.000
% DEGRADATION TRANSIENT (N)	0.000	100.000	0.000	0.084	1.285	3.132	8.124	18.805	49.858	65.115	100.000
% DEGRADATION DEFROST (N)	0.000	0.000	2.186	2.467	4.515	2.385	0.000	0.000	0.000	0.000	0.000
% DEGRADATION STRIP HEAT(N)	0.000	0.000	37.241	13.743	0.752	0.000	0.000	0.000	0.000	0.000	0.000
% DEGRADATION CRANKCASE (N)	0.000	100.000	0.000	0.038	0.620	1.497	5.415	17.225	49.486	64.672	100.000
% DEGRADATION TRANSIENT (SS)	0.000	0.000	-0.020	-0.136	-0.144	1.606	4.768	8.402	6.137	5.342	0.000
% DEGRADATION DEFROST (SS)	0.000	0.000	1.866	2.176	4.367	2.333	0.000	0.000	0.000	0.000	0.000
% DEGRADATION STRIP HEAT (SS)	0.000	0.000	34.645	12.606	0.738	0.000	0.000	0.000	0.000	0.000	0.000
% DEGRADATION CRANKCASE (SS)	0.000	100.000	0.000	0.034	0.608	1.503	5.647	19.144	53.767	69.163	100.000
TOTAL BIN HOUR COUNT	0.000	1.000	38.000	96.000	248.000	315.000	135.000	123.000	160.000	69.000	9.000
TOTAL RUNTIME SUM (HR)	0.000	0.000	38.436	93.423	166.130	139.047	23.219	6.379	1.795	0.377	0.000
KW OF TOTAL INPUT	0.000	0.042	181.761	336.486	567.195	498.395	87.284	28.516	13.476	4.470	0.381
KW BASED ON COPSS	0.000	0.042	195.382	366.849	578.154	496.293	83.694	25.657	12.403	4.180	0.381
KW BASED ON COPN	0.000	0.042	179.267	328.993	534.360	471.146	82.560	26.898	12.955	4.299	0.381
KW OF TOTAL INPUT (NO NOR STRIP)	0.000	0.042	114.072	290.242	562.930	498.395	87.284	28.516	13.476	4.470	0.381
KW BASED ON COPSS (NO NOR STRIP)	0.000	0.042	127.692	320.604	573.888	496.293	83.694	25.657	12.403	4.180	0.381

NORMAL DEGRADATIONS FACTORS:

TRANSIENT= 2.8 DEFROST= 3.9 STRIP HEAT= 6.9 CRANKCASE= 1.9

STEADY STATE DEGRADATION FACTORS:

TRANSIENT= 0.8 DEFROST= 2.8 STRIP HEAT= 6.7 CRANKCASE= 1.8

A.2 Dual-Speed Mode Heating Bin Data Results

	-25/-20	-20/-15	-15/-10	-10/-5	-5/0	0/5	5/10	10/15	15/20	20/25	25/30
AVERAGE BIN TEMPERATURE (C)	-23.193	-17.503	-11.865	-6.892	-1.545	2.346	7.407	11.993	16.849	20.880	0.000
AVERAGE BIN REL. HUMIDITY (%)	42.510	58.689	69.158	61.583	58.359	60.628	61.718	48.432	30.502	38.760	0.000
# OF HOURS IN BIN	3.000	15.000	10.000	46.000	145.000	233.000	227.000	144.000	28.000	3.000	0.000
TRANSIENT OPERATING TIME (HR)	0.000	0.667	0.000	1.067	18.467	34.133	30.400	14.333	2.600	0.267	0.000
NORMAL OPERATING TIME (HR)	3.019	12.139	10.077	42.916	75.542	84.804	42.156	15.734	2.279	0.253	0.000
DEFROST OPERATING TIME (HR)	0.000	0.000	0.431	0.366	1.623	2.184	0.079	0.000	0.000	0.000	0.000
# OF START-UP CYCLES	0.000	10.000	0.000	16.000	277.000	512.000	456.000	229.000	39.000	4.000	0.000
# OF DEFROST CYCLES	0.000	0.000	3.000	3.000	14.000	21.000	1.000	0.000	0.000	0.000	0.000
TRANSIENT INPUT ENERGY (KW-HR)	0.000	1.944	0.000	3.484	57.304	95.167	67.617	32.214	5.083	0.572	0.000
NORMAL INPUT ENERGY (KW-HR)	7.209	31.838	27.347	124.267	229.572	240.998	103.069	37.744	5.738	0.593	0.000
DEFROST INPUT ENERGY (KW-HR)	0.000	0.000	1.262	1.168	5.242	5.586	0.389	0.000	0.000	0.000	0.000
TOTAL CRANKCASE INPUT (KW-HR)	0.000	0.094	0.000	0.070	2.091	4.904	8.927	10.383	4.618	2.112	0.166
TOTAL ENERGY INPUT (KW-HR)	7.209	33.875	28.609	128.989	294.209	346.655	180.002	80.340	15.439	3.277	0.166
TRANSIENT OUTPUT ENERGY (KW-HR)	0.000	4.768	0.000	7.837	133.460	220.201	161.378	77.879	13.218	1.664	0.000
NORMAL OUTPUT ENERGY (KW-HR)	34.268	100.512	65.230	289.661	567.292	616.020	280.114	108.211	17.705	1.990	0.000
DEFROST OUTPUT ENERGY (KW-HR)	0.000	0.000	1.965	1.740	8.154	8.943	0.642	0.000	0.000	0.000	0.000
TOTAL OUTPUT ENERGY (KW-HR)	34.268	105.280	67.196	299.238	708.907	845.165	442.134	186.090	30.922	3.654	0.000
NORMAL STRIP HEAT (KW-HR)	24.918	49.440	11.604	2.304	1.629	0.000	0.000	0.000	0.000	0.000	0.000
DEFROST STRIP HEAT (KW-HR)	0.000	0.000	5.232	4.176	17.504	17.341	0.941	0.000	0.000	0.000	0.000
TRANSIENT COP	0.000	2.453	0.000	2.249	2.329	2.314	2.387	2.418	2.600	2.911	0.000
NORMAL COP (WITHOUT STRIP)	1.297	1.604	1.961	2.312	2.464	2.556	2.718	2.867	3.086	3.357	0.000
TR+NOR COP (WITHOUT STRIP)	1.297	1.648	1.961	2.309	2.419	2.452	2.458	2.316	2.003	1.115	0.000
NORMAL COP (WITH STRIP)	1.067	1.237	1.675	2.289	2.454	2.556	2.718	2.867	3.086	3.357	0.000
DEFROST COP (WITH STRIP)	0.000	0.000	0.303	0.326	0.358	0.390	0.483	0.000	0.000	0.000	0.000
OVERALL COP	1.067	1.264	1.479	2.209	2.262	2.322	2.444	2.316	2.003	1.115	0.000
# OF LOW SPEED CYCLES	0.000	1.000	0.000	0.000	3.000	210.000	406.000	211.000	39.000	4.000	0.000
# OF HIGH SPEED CYCLES	0.000	9.000	0.000	16.000	274.000	302.000	50.000	18.000	0.000	0.000	0.000
LOW SPEED STRIP HEAT (KW-HR)	0.000	0.000	0.000	0.000	0.162	0.016	0.000	0.000	0.000	0.000	0.000
% TIME IN DEFROST	0.000	0.002	4.098	0.824	1.697	1.803	0.109	0.000	0.000	0.000	0.000
% TIME IN TRANSIENT	0.000	5.206	0.000	2.405	19.310	28.181	41.853	47.670	53.291	51.337	0.000
OVERALL COP (WITHOUT NOR STRIP)	1.297	1.648	1.643	2.230	2.269	2.322	2.444	2.316	2.003	1.115	0.000
% DEGRADATION TRANSIENT (N)	-0.000	0.340	0.000	0.112	1.417	2.421	6.139	13.764	28.949	64.423	100.000
% DEGRADATION DEFROST (N)	0.000	-0.008	16.198	3.402	6.218	5.368	1.987	0.000	0.000	0.000	0.000
% DEGRADATION STRIP HEAT (N)	77.561	59.341	25.534	1.701	0.520	0.000	0.000	0.000	0.000	0.000	0.000
% DEGRADATION CRANKCASE (N)	0.000	0.276	0.000	0.053	0.671	1.347	4.934	12.923	29.909	64.459	100.000
% DEGRADATION TRANSIENT (SS)	0.000	-3.719	0.000	-0.297	-1.050	1.483	7.316	11.572	10.130	4.343	0.000
% DEGRADATION DEFROST (SS)	0.000	0.000	16.118	2.886	5.860	5.436	0.665	0.000	0.000	0.000	0.000
% DEGRADATION STRIP HEAT (SS)	75.191	55.505	26.058	1.473	0.499	0.000	0.000	0.000	0.000	0.000	0.000
% DEGRADATION CRANKCASE (SS)	0.000	0.236	0.000	0.046	0.644	1.395	5.485	15.147	34.574	68.695	100.000
TOTAL BIN HOUR COUNT	3.000	15.000	10.000	46.000	145.000	237.000	286.000	277.000	115.000	51.000	4.000
TOTAL RUNTIME SUM (HR)	3.019	12.806	10.508	44.348	95.631	121.122	72.636	30.068	4.879	0.519	0.000
KW OF TOTAL INPUT	32.127	83.315	45.445	135.469	313.342	363.995	180.943	80.340	15.439	3.277	0.166
KW BASED ON COPSS	33.139	89.072	44.532	156.439	326.368	351.519	162.772	68.546	13.356	3.075	0.166
KW BASED ON COPN	32.127	83.197	39.963	130.738	289.406	335.833	171.267	74.969	14.623	3.176	0.166
KW OF TOTAL INPUT (NO NOR STRIP)	7.209	33.875	33.841	133.165	311.712	363.995	180.943	80.340	15.439	3.277	0.166
KW BASED ON COPSS (NO NOR STRIP)	8.221	39.632	32.928	154.135	324.739	351.519	162.772	68.546	13.356	3.075	0.166

NORMAL DEGRADATIONS FACTORS:

TRANSIENT= 3.6 DEFROST= 5.5 STRIP HEAT= 7.2 CRANKCASE= 2.9

STEADY STATE DEGRADATION FACTORS:

TRANSIENT= 1.8 DEFROST= 4.2 STRIP HEAT= 7.2 CRANKCASE= 2.9

A.3 Dual-Speed Mode (Low Hours Only) Heating Bin Data Results

	-25/-20	-20/-15	-15/-10	-10/-5	-5/0	0/5	5/10	10/15	15/20	20/25	25/30
AVERAGE BIN TEMPERATURE (C)	0.000	0.000	0.000	0.000	-1.080	3.306	7.476	12.030	16.849	20.880	0.000
AVERAGE BIN REL. HUMIDITY (%)	0.000	0.000	0.000	0.000	38.742	60.907	63.748	49.129	30.502	38.760	0.000
# OF HOURS IN BIN	0.000	0.000	0.000	0.000	5.000	89.000	202.000	137.000	28.000	3.000	0.000
TRANSIENT OPERATING TIME (HR)	0.000	0.000	0.000	0.000	0.000	12.400	26.400	13.400	2.600	0.267	0.000
NORMAL OPERATING TIME (HR)	0.000	0.000	0.000	0.000	5.033	30.014	34.762	14.320	2.279	0.253	0.000
DEFROST OPERATING TIME (HR)	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
# OF START-UP CYCLES	0.000	0.000	0.000	0.000	0.000	186.000	396.000	215.000	39.000	4.000	0.000
# OF DEFROST CYCLES	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TRANSIENT INPUT ENERGY (KW-HR)	0.000	0.000	0.000	0.000	0.000	27.511	56.864	29.465	5.083	0.572	0.000
NORMAL INPUT ENERGY (KW-HR)	0.000	0.000	0.000	0.000	10.243	65.855	78.647	33.198	5.738	0.593	0.000
DEFROST INPUT ENERGY (KW-HR)	0.000	0.000	0.000	0.000	0.000	0.000	0.058	0.000	0.000	0.000	0.000
TOTAL CRANKCASE INPUT (KW-HR)	0.000	0.000	0.000	0.000	0.116	1.782	7.528	9.571	4.618	2.112	0.000
TOTAL ENERGY INPUT (KW-HR)	0.000	0.000	0.000	0.000	10.358	95.148	143.097	72.235	15.439	3.277	0.000
TRANSIENT OUTPUT ENERGY (KW-HR)	0.000	0.000	0.000	0.000	0.000	61.258	136.505	71.691	13.218	1.664	0.000
NORMAL OUTPUT ENERGY (KW-HR)	0.000	0.000	0.000	0.000	22.022	163.260	216.026	95.881	17.705	1.990	0.000
DEFROST OUTPUT ENERGY (KW-HR)	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
TOTAL OUTPUT ENERGY (KW-HR)	0.000	0.000	0.000	0.000	22.022	224.519	352.532	167.571	30.922	3.654	0.000
NORMAL STRIP HEAT (KW-HR)	0.000	0.000	0.000	0.000	0.138	0.000	0.000	0.000	0.000	0.000	0.000
DEFROST STRIP HEAT (KW-HR)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TRANSIENT COP	0.000	0.000	0.000	0.000	0.000	2.227	2.401	2.433	2.600	2.911	0.000
NORMAL COP (WITHOUT STRIP)	0.000	0.000	0.000	0.000	2.137	2.479	2.747	2.888	3.086	3.357	0.000
TR+NOR COP (WITHOUT STRIP)	0.000	0.000	0.000	0.000	2.113	2.360	2.465	2.320	2.003	1.115	0.000
NORMAL COP (WITH STRIP)	0.000	0.000	0.000	0.000	2.121	2.479	2.747	2.888	3.086	3.357	0.000
DEFROST COP (WITH STRIP)	0.000	0.000	0.000	0.000	0.000	0.000	0.011	0.000	0.000	0.000	0.000
OVERALL COP	0.000	0.000	0.000	0.000	2.098	2.360	2.464	2.320	2.003	1.115	0.000
# OF LOW SPEED CYCLES	0.000	0.000	0.000	0.000	0.000	186.000	396.000	208.000	39.000	4.000	0.000
# OF HIGH SPEED CYCLES	0.000	0.000	0.000	0.000	0.000	0.000	0.000	7.000	0.000	0.000	0.000
LOW SPEED STRIP HEAT (KW-HR)	0.000	0.000	0.000	0.000	0.138	0.000	0.000	0.000	0.000	0.000	0.000
% TIME IN DEFROST	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.000
% TIME IN TRANSIENT	0.000	0.000	0.000	0.000	0.000	29.236	43.163	48.341	53.291	51.337	0.000
OVERALL COP (WITHOUT NOR STRIP)	0.000	0.000	0.000	0.000	2.113	2.360	2.464	2.320	2.003	1.115	0.000
% DEGRADATION TRANSIENT (N)	0.000	0.000	0.000	0.000	1.116	2.452	6.280	13.794	28.949	64.423	100.000
% DEGRADATION DEFROST (N)	0.000	0.000	0.000	0.000	0.000	0.000	1.209	0.000	0.000	0.000	0.000
% DEGRADATION STRIP HEAT (N)	0.000	0.000	0.000	0.000	1.315	0.000	0.000	0.000	0.000	0.000	0.000
% DEGRADATION CRANKCASE (N)	0.000	0.000	0.000	0.000	1.116	1.873	5.261	13.250	29.909	64.459	100.000
% DEGRADATION TRANSIENT (SS)	0.000	0.000	0.000	0.000	0.000	5.631	8.267	11.936	10.130	4.343	0.000
% DEGRADATION DEFROST (SS)	0.000	0.000	0.000	0.000	0.000	0.000	0.045	0.000	0.000	0.000	0.000
% DEGRADATION STRIP HEAT (SS)	0.000	0.000	0.000	0.000	1.479	0.000	0.000	0.000	0.000	0.000	0.000
% DEGRADATION CRANKCASE (SS)	0.000	0.000	0.000	0.000	1.258	2.085	5.906	15.610	34.574	68.695	100.000
TOTAL BIN HOUR COUNT	3.000	15.000	10.000	46.000	145.000	237.000	286.000	277.000	115.000	51.000	4.000
TOTAL RUNTIME SUM (HR)	0.000	0.000	0.000	0.000	5.033	42.414	61.163	27.720	4.879	0.519	0.000
KW OF TOTAL INPUT	0.000	0.000	0.000	0.000	10.496	95.148	143.097	72.235	15.439	3.277	0.000
KW BASED ON COPSS	0.000	0.000	0.000	0.000	9.332	85.446	127.460	61.316	13.356	3.075	0.000
KW BASED ON COPN	0.000	0.000	0.000	0.000	10.496	92.632	135.751	67.340	14.623	3.176	0.000
KW OF TOTAL INPUT (NO NOR STRIP)	0.000	0.000	0.000	0.000	10.358	95.148	143.097	72.235	15.439	3.277	0.000
KW BASED ON COPSS (NO NOR STRIP)	0.000	0.000	0.000	0.000	9.194	85.446	127.460	61.316	13.356	3.075	0.000

NORMAL DEGRADATIONS FACTORS:

TRANSIENT= 8.2 DEFROST= 0.0 STRIP HEAT= 0.0 CRANKCASE= 7.6

STEADY STATE DEGRADATION FACTORS:

TRANSIENT= 8.1 DEFROST= 0.0 STRIP HEAT= 0.0 CRANKCASE= 8.6

A.4 Dual-Speed Mode (High Hours Only) Heating Bin Data Results

	-25/-20	-20/-15	-15/-10	-10/-5	-5/0	0/5	5/10	10/15	15/20	20/25	25/30
AVERAGE BIN TEMPERATURE (C)	-23.193	-17.483	-11.865	-6.892	-1.574	1.823	6.564	12.050	0.000	0.000	0.000
AVERAGE BIN REL. HUMIDITY (%)	42.510	55.738	69.158	61.583	59.267	60.223	45.742	34.207	0.000	0.000	0.000
# OF HOURS IN BIN	3.000	14.000	10.000	46.000	138.000	127.000	17.000	3.000	0.000	0.000	0.000
TRANSIENT OPERATING TIME (HR)	0.000	0.467	0.000	1.067	18.133	18.933	2.800	0.400	0.000	0.000	0.000
NORMAL OPERATING TIME (HR)	3.019	11.765	10.077	42.916	69.694	48.083	5.259	0.463	0.000	0.000	0.000
DEFROST OPERATING TIME (HR)	0.000	0.000	0.431	0.366	1.623	1.630	0.078	0.000	0.000	0.000	0.000
# OF START-UP CYCLES	0.000	7.000	0.000	16.000	272.000	284.000	42.000	19.000	0.000	0.000	0.000
# OF DEFROST CYCLES	0.000	0.000	3.000	3.000	14.000	17.000	1.000	0.000	0.000	0.000	0.000
TRANSIENT INPUT ENERGY (KW-HR)	0.000	1.511	0.000	3.484	56.685	60.057	7.731	1.101	0.000	0.000	0.000
NORMAL INPUT ENERGY (KW-HR)	7.209	30.551	27.347	124.267	216.842	156.394	18.778	1.887	0.006	0.014	0.000
DEFROST INPUT ENERGY (KW-HR)	0.000	0.000	1.262	1.168	5.242	5.532	0.389	0.000	0.000	0.000	0.000
TOTAL CRANKCASE INPUT (KW-HR)	0.000	0.089	0.000	0.086	2.018	2.815	0.992	0.299	0.000	0.000	0.000
TOTAL ENERGY INPUT (KW-HR)	7.209	32.152	28.609	129.005	280.787	224.797	27.890	3.287	0.006	0.014	0.000
TRANSIENT OUTPUT ENERGY (KW-HR)	0.000	3.656	0.000	7.837	132.321	142.105	17.888	2.388	0.000	0.000	0.000
NORMAL OUTPUT ENERGY (KW-HR)	34.268	97.205	65.230	289.661	540.070	405.649	49.166	5.079	0.000	0.000	0.000
DEFROST OUTPUT ENERGY (KW-HR)	0.000	0.000	1.965	1.740	8.154	8.768	0.642	0.000	0.000	0.000	0.000
TOTAL OUTPUT ENERGY (KW-HR)	34.268	100.861	67.196	299.238	680.546	556.522	67.696	7.466	0.000	0.000	0.000
NORMAL STRIP HEAT (KW-HR)	24.918	49.440	11.604	2.304	1.467	0.000	0.000	0.000	0.000	0.000	0.000
DEFROST STRIP HEAT (KW-HR)	0.000	0.000	5.232	4.176	17.504	17.325	0.941	0.000	0.000	0.000	0.000
TRANSIENT COP	0.000	2.419	0.000	2.269	2.334	2.366	2.314	2.168	0.000	0.000	0.000
NORMAL COP (WITHOUT STRIP)	1.297	1.563	1.961	2.312	2.484	2.594	2.618	2.691	0.000	0.000	0.000
TR-NOR COP (WITHOUT STRIP)	1.297	1.599	1.961	2.309	2.435	2.498	2.438	2.271	0.000	0.000	0.000
NORMAL COP (WITH STRIP)	1.067	1.215	1.675	2.289	2.474	2.594	2.618	2.691	0.000	0.000	0.000
DEFROST COP (WITH STRIP)	0.000	0.000	0.303	0.326	0.358	0.384	0.483	0.000	0.000	0.000	0.000
OVERALL COP	1.067	1.236	1.479	2.209	2.270	2.299	2.348	2.271	0.000	0.000	0.000
# OF LOW SPEED CYCLES	0.000	0.000	0.000	0.000	0.000	0.000	0.000	6.000	0.000	0.000	0.000
# OF HIGH SPEED CYCLES	0.000	7.000	0.000	16.000	272.000	284.000	42.000	13.000	0.000	0.000	0.000
LOW SPEED STRIP HEAT (KW-HR)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
% TIME IN DEFROST	0.000	0.000	4.098	0.824	1.814	2.374	0.963	0.000	0.000	0.000	0.000
% TIME IN TRANSIENT	0.000	3.815	0.000	2.405	20.272	27.581	34.411	46.332	0.000	0.000	0.000
OVERALL COP (WITHOUT NOR STRIP)	1.297	1.599	1.643	2.230	2.277	2.299	2.348	2.271	0.000	0.000	0.000
% DEGRADATION TRANSIENT (N)	-0.000	0.402	0.000	0.123	1.448	2.367	5.591	14.641	100.000	100.000	100.000
% DEGRADATION DEFROST (N)	0.000	0.000	16.198	3.413	6.486	8.138	6.044	0.000	0.000	0.000	0.000
% DEGRADATION STRIP HEAT (N)	77.561	60.594	25.534	1.701	0.489	0.000	0.000	0.000	0.000	0.000	0.000
% DEGRADATION CRANKCASE (N)	0.000	0.278	0.000	0.064	0.676	1.162	3.440	9.082	0.000	0.000	100.000
% DEGRADATION TRANSIENT (SS)	0.000	-3.023	0.000	-0.297	-1.133	-0.122	2.997	8.666	0.000	0.000	0.000
% DEGRADATION DEFROST (SS)	0.000	0.000	16.118	2.886	6.082	7.980	3.988	0.000	0.000	0.000	0.000
% DEGRADATION STRIP HEAT (SS)	75.191	57.577	26.058	1.473	0.467	0.000	0.000	0.000	0.000	0.000	0.000
% DEGRADATION CRANKCASE (SS)	0.000	0.245	0.000	0.056	0.645	1.175	3.652	10.104	0.000	0.000	100.000
TOTAL BIN HOUR COUNT	3.000	15.000	10.000	46.000	145.000	237.000	286.000	277.000	115.000	51.000	4.000
TOTAL RUNTIME SUM (HR)	3.019	12.231	10.508	44.348	89.449	68.646	8.137	0.863	0.000	0.000	0.000
KW OF TOTAL INPUT	32.127	81.592	45.445	135.485	299.758	242.122	28.831	3.287	0.006	0.014	0.000
KW BASED ON COPSS	33.139	85.867	44.532	156.455	314.359	239.514	27.163	2.955	0.000	0.000	0.000
KW BASED ON COPN	32.127	81.474	39.963	130.754	275.882	217.229	26.800	3.015	0.000	0.000	0.000
KW OF TOTAL INPUT (NO NOR STRIP)	7.209	32.152	33.841	133.181	298.291	242.122	28.831	3.287	0.006	0.014	0.000
KW BASED ON COPSS (NO NOR STRIP)	8.221	36.427	32.928	154.151	312.892	239.514	27.163	2.955	0.000	0.000	0.000

NORMAL DEGRADATIONS FACTORS:

TRANSIENT= 1.6 DEFROST= 6.6 STRIP HEAT=10.3 CRANKCASE= 0.8

STEADY STATE DEGRADATION FACTORS:

TRANSIENT=-0.5 DEFROST= 6.0 STRIP HEAT= 9.9 CRANKCASE= 0.8

A.5 Single-Speed Mode Cooling Bin Data Results

	0/5	5/10	10/15	15/20	20/25	25/30	30/35	35/40	40/45	45/50
AVERAGE BIN TEMPERATURE (C)	0.000	0.000	0.000	18.807	22.175	27.449	31.486	0.000	0.000	0.000
AVERAGE BIN REL. HUMDITY (%)	0.000	0.000	0.000	72.699	68.649	54.685	48.591	0.000	0.000	0.000
# OF HOURS IN BIN	0.000	0.000	0.000	116.000	357.000	237.000	84.000	0.000	0.000	0.000
TRANSIENT OPERATING TIME (HR)	0.000	0.000	0.000	7.333	26.733	20.600	7.733	0.000	0.000	0.000
NORMAL OPERATING TIME (HR)	0.000	0.000	0.000	12.855	71.786	85.712	35.897	0.000	0.000	0.000
# OF START-UP CYCLES	0.000	0.000	0.000	110.000	401.000	309.000	116.000	0.000	0.000	0.000
TRANSIENT INPUT ENERGY (KW-HR)	0.000	0.000	0.000	23.441	89.594	74.322	29.613	0.000	0.000	0.000
NORMAL INPUT ENERGY (KW-HR)	0.000	0.000	0.000	45.566	259.165	314.924	135.592	0.000	0.000	0.000
TOTAL CRANKCASE INPUT (KW-HR)	0.000	0.549	1.507	8.162	14.713	6.072	1.767	0.000	0.000	0.000
TOTAL ENERGY INPUT (KW-HR)	0.000	0.549	1.507	77.170	363.472	395.317	166.972	0.000	0.000	0.000
TRANSIENT OUTPUT ENERGY (KW-HR)	0.000	0.000	0.000	44.711	175.880	131.323	50.199	0.000	0.000	0.000
NORMAL OUTPUT ENERGY (KW-HR)	0.000	0.000	0.000	111.395	603.644	699.408	286.162	0.000	0.000	0.000
LATENT LOAD (KW-HR)	0.000	0.000	0.000	40.236	206.170	211.714	81.677	0.000	0.000	0.000
TOTAL OUTPUT ENERGY (KW-HR)	0.000	0.000	0.000	156.105	779.524	830.731	336.361	0.000	0.000	0.000
CONDENSATE COLLECTED (KG)	0.000	0.000	0.000	58.690	300.840	308.920	119.150	0.000	0.000	0.000
TRANSIENT COP (WITHOUT CRANKCASE)	0.000	0.000	0.000	1.907	1.963	1.767	1.695	0.000	0.000	0.000
NORMAL COP (WITHOUT CRANKCASE)	0.000	0.000	0.000	2.445	2.329	2.221	2.110	0.000	0.000	0.000
OVERALL COP (WITHOUT CRANKCASE)	0.000	0.000	0.000	2.262	2.235	2.134	2.036	0.000	0.000	0.000
OVERALL COP (WITH CRANKCASE)	0.000	0.000	0.000	2.023	2.145	2.101	2.014	0.000	0.000	0.000
# OF LOW SPEED CYCLES	0.000	0.000	0.000	0.000	1.000	1.000	0.000	0.000	0.000	0.000
# OF HIGH SPEED CYCLES	0.000	0.000	0.000	110.000	400.000	308.000	116.000	0.000	0.000	0.000
SENSIBLE OUTPUT ENERGY (KW-HR)	0.000	0.000	0.000	115.869	573.405	619.017	254.685	0.000	0.000	0.000
SENSIBLE HEAT RATIO	0.000	0.000	0.000	0.742	0.736	0.745	0.757	0.000	0.000	0.000
% TIME IN TRANSIENT	0.000	0.000	0.000	36.324	27.135	19.377	17.725	0.000	0.000	0.000
HIGH SPEED RUNTIME (HR)	0.000	0.000	0.000	20.189	98.518	106.311	43.630	0.000	0.000	0.000
LOW SPEED RUNTIME (HR)	0.000	0.000	0.000	0.000	0.002	0.001	0.000	0.000	0.000	0.000
TOTAL HOURS IN BIN	0.000	13.000	36.000	214.000	451.000	253.000	88.000	0.000	0.000	0.000
TRANSIENT SENSIBLE HEAT FLOW(KW-HR)	0.000	0.000	0.000	34.990	132.359	106.843	41.448	0.000	0.000	0.000
NORMAL SENSIBLE HEAT FLOW (KW-HR)	0.000	0.000	0.000	80.879	441.046	512.174	213.237	0.000	0.000	0.000
TOTAL OPERATING TIME (HR)	0.000	0.000	0.000	20.189	98.519	106.312	43.630	0.000	0.000	0.000
% DEGRADATION TRANSIENT (N)	0.000	0.000	48.925	11.016	0.616	2.924	2.368	0.000	0.000	0.000
% DEGRADATION CRANKCASE (N)	0.000	100.000	100.000	10.577	4.048	1.536	1.058	0.000	0.000	0.000
% DEGRADATION TRANSIENT (SS)	0.000	0.000	0.000	16.585	11.585	9.078	7.990	0.000	0.000	0.000
% DEGRADATION CRANKCASE (SS)	0.000	100.000	99.885	14.274	5.338	2.000	1.352	0.000	0.000	0.000
KW OF ACTUAL INPUT	0.000	0.549	1.507	77.170	363.472	395.317	166.972	0.000	0.000	0.000
KW BASED ON COPSS	0.000	0.549	1.508	57.184	275.611	303.602	130.690	0.000	0.000	0.000
KW BASED ON COPN	0.000	0.549	1.509	69.200	361.780	383.784	163.082	0.000	0.000	0.000
TRANSIENT LATENT OUTPUT (KW-HR)	0.000	0.000	0.000	9.721	43.521	24.480	8.751	0.000	0.000	0.000
NORMAL LATENT OUTPUT (KW-HR)	0.000	0.000	0.000	30.515	162.598	187.234	72.925	0.000	0.000	0.000

NORMAL DEGRADATION FACTORS:

TRANSIENT= 2.7 CRANKCASE= 3.3

STEADY STATE DEGRADATION FACTORS:

TRANSIENT=10.3 CRANKCASE= 4.3

A.6 Dual-Speed Mode Cooling Bin Data Results

	0/5	5/10	10/15	15/20	20/25	25/30	30/35	35/40	40/45	45/50
AVERAGE BIN TEMPERATURE (C)	0.000	0.000	14.400	18.564	22.077	27.439	31.424	37.720	0.000	0.000
AVERAGE BIN REL. HUMIDITY (%)	0.000	0.000	69.203	71.752	69.618	51.909	50.160	48.050	0.000	0.000
# OF HOURS IN BIN	0.000	0.000	3.000	136.000	352.000	205.000	89.000	2.000	0.000	0.000
TRANSIENT OPERATING TIME (HR)	0.000	0.000	0.200	10.533	37.200	15.667	6.000	0.133	0.000	0.000
NORMAL OPERATING TIME (HR)	0.000	0.000	0.367	21.206	85.598	109.449	56.762	1.501	0.000	0.000
# OF START-UP CYCLES	0.000	0.000	3.000	158.000	558.000	235.000	90.000	2.000	0.000	0.000
TRANSIENT INPUT ENERGY (KW-HR)	0.000	0.000	0.310	19.906	61.306	34.285	15.276	0.292	0.000	0.000
NORMAL INPUT ENERGY (KW-HR)	0.000	0.000	0.783	46.067	205.779	247.308	130.181	3.369	0.000	0.000
TOTAL CRANKCASE INPUT (KW-HR)	0.000	0.546	2.506	6.819	11.246	4.182	1.170	0.015	0.000	0.000
TOTAL ENERGY INPUT (KW-HR)	0.000	0.546	3.599	72.791	278.331	285.775	146.627	3.677	0.000	0.000
TRANSIENT OUTPUT ENERGY (KW-HR)	0.000	0.000	0.669	43.303	133.057	69.652	30.259	0.606	0.000	0.000
NORMAL OUTPUT ENERGY (KW-HR)	0.000	0.000	1.861	115.509	511.078	582.888	297.005	8.080	0.000	0.000
LATENT LOAD (KW-HR)	0.000	0.000	0.000	19.645	105.549	96.228	53.818	1.625	0.000	0.000
TOTAL OUTPUT ENERGY (KW-HR)	0.000	0.000	2.530	158.812	644.134	652.539	327.263	8.686	0.000	0.000
CONDENSATE COLLECTED (KG)	0.000	0.000	0.000	28.660	153.920	140.380	78.340	2.370	0.000	0.000
TRANSIENT COP (WITHOUT CRANKCASE)	0.000	0.000	2.161	2.175	2.170	2.032	1.981	2.077	0.000	0.000
NORMAL COP (WITHOUT CRANKCASE)	0.000	0.000	2.377	2.507	2.484	2.357	2.281	2.398	0.000	0.000
OVERALL COP (WITHOUT CRANKCASE)	0.000	0.000	2.316	2.407	2.412	2.317	2.250	2.372	0.000	0.000
OVERALL COP (WITH CRANKCASE)	0.000	0.000	0.703	2.182	2.314	2.283	2.232	2.363	0.000	0.000
# OF LOW SPEED CYCLES	0.000	0.000	3.000	154.000	460.000	233.000	90.000	2.000	0.000	0.000
# OF HIGH SPEED CYCLES	0.000	0.000	0.000	4.000	98.000	2.000	0.000	0.000	0.000	0.000
SENSIBLE OUTPUT ENERGY (KW-HR)	0.000	0.000	2.530	139.168	538.586	556.311	273.445	7.061	0.000	0.000
SENSIBLE HEAT RATIO	0.000	0.000	1.000	0.876	0.836	0.853	0.836	0.813	0.000	0.000
% TIME IN TRANSIENT	0.000	0.000	35.277	33.187	30.294	12.522	9.560	8.159	0.000	0.000
HIGH SPEED RUNTIME (HR)	0.000	0.000	0.000	0.001	0.574	2.779	0.000	0.000	0.000	0.000
LOW SPEED RUNTIME (HR)	0.000	0.000	0.567	31.738	122.224	122.337	62.762	1.634	0.000	0.000
TOTAL HOURS IN BIN	8.000	13.000	60.000	194.000	390.000	225.000	91.000	2.000	0.000	0.000
TRANSIENT SENSIBLE HEAT FLOW(KW-HR)	0.000	0.000	0.669	38.228	115.685	63.746	27.591	0.537	0.000	0.000
NORMAL SENSIBLE HEAT FLOW (KW-HR)	0.000	0.000	1.861	100.940	422.900	492.565	245.854	6.524	0.000	0.000
TOTAL OPERATING TIME (HR)	0.000	0.000	0.567	31.739	122.798	125.116	62.762	1.634	0.000	0.000
% DEGRADATION TRANSIENT (N)	0.000	84.679	22.874	2.502	0.785	0.582	0.515	1.060	0.000	0.000
% DEGRADATION CRANKCASE (N)	0.000	100.000	69.638	9.368	4.041	1.463	0.798	0.418	0.000	0.000
% DEGRADATION TRANSIENT (SS)	0.000	0.000	4.109	14.157	9.910	4.835	3.492	0.959	0.000	0.000
% DEGRADATION CRANKCASE (SS)	0.000	100.000	78.708	12.852	5.366	1.855	0.968	0.416	0.000	0.000
KW OF ACTUAL INPUT	0.000	0.546	3.599	72.791	278.331	285.775	146.627	3.677	0.000	0.000
KW BASED ON COPSS	0.000	0.546	3.184	53.055	209.593	225.436	120.937	3.691	0.000	0.000
KW BASED ON COPN	0.000	0.546	3.573	71.206	276.213	284.112	145.900	3.638	0.000	0.000
TRANSIENT LATENT OUTPUT (KW-HR)	0.000	0.000	0.000	5.076	17.371	5.906	2.668	0.069	0.000	0.000
NORMAL LATENT OUTPUT (KW-HR)	0.000	0.000	0.000	14.569	88.177	90.322	51.150	1.556	0.000	0.000

NORMAL DEGRADATION FACTORS:

TRANSIENT= 1.0 CRANKCASE= 3.3

STEADY-STATE DEGRADATION FACTORS:

TRANSIENT= 7.1 CRANKCASE= 4.3

A.7 Single and Dual-Speed Mode's Heating Analysis Computer Program

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REAL VALUE(40),BINVA(11,63)
REAL COPN,IFTOT,OFTOT,COMTOT,SHTOT,RTHR,CCTOT,NORIN
REAL KWACT,KWDEIN,KWTRIN,TOTOUT,KWSS,COPSS,COPSSL,COPSSH
REAL KWMTLN,KWMDLN,KWMSHL,KWMCCL,KWATOT,KWANSH,LSSH
REAL KWMTLS,KWMDLS,KWMSHS,KWMCSS,KWSSTO,KWSSENS
DIMENSION A(53)
INTEGER IDAYS
OPEN(UNIT=45,FILE='SILVER.DAT')
101 OPEN(UNIT=44,FILE='BIN.DAT')
WRITE(5,327)
327 FORMAT(' WHAT IS THE INPUT FILE')
READ(5,328)FNAM
328 FORMAT(A6)
WRITE(5,329)FNAM
329 FORMAT(' FOR THE WEEK ',A6,' HOW MANY DAYS ARE THERE')
READ(5,330)DAYS
330 FORMAT(F10.0)
IF(DAYS.GE.43)GOTO 843
IDAYS=DAYS
IHOURS=IDAYS*24
800 READ(44,844)TLOW,THIGH,I
844 FORMAT(2F10.4,I2)
IF(TLOW.EQ.843)CLOSE(UNIT=44)
IF(TLOW.EQ.843)GOTO 101
OPEN(UNIT=43,FILE=FNAM)
OPEN(UNIT=47,FILE='NAMBI1.DAT')
DO 750 II=1,IHOURS
  READ(43,250)(VALUE(J),J=1,40)
250  FORMAT(8F10.4)
  DO 270 K=1,40
    IF(VALUE(K).EQ.99999)GOTO 750
270  CONTINUE
  IF(VALUE(33).LT.-30.0)WRITE(5,78)
78  FORMAT('LOWER THAN -30 C')
  IF(VALUE(33).GE.30.0)WRITE(5,79)
79  FORMAT('EQUAL OR GREATER THAN 30 C')
  IF((VALUE(33).LT.TLOW).OR.(VALUE(33).GE.THIGH))
*GO TO 750
  LSSH=0.
  IF(VALUE(23).LT.27.) GO TO 95
  LSSH=VALUE(15)
95  IF(LSSH.GT.100) WRITE(5,1313) FNAM,II
1313 FORMAT(' HEY BUCKO, FNAM=',A5,' FOR II=',I3)
  IF(LSSH.GT.100) GO TO 750
  BINVA(I,44)=BINVA(I,44)+(VALUE(17)/1000.)
  BINVA(I,58)=BINVA(I,58)+(VALUE(22)/3600.)
  BINVA(I,59)=BINVA(I,59)+(VALUE(23)/3600.)
  IF(VALUE(23).GT.10) GO TO 93

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          BINVA(I,61)=BINVA(I,61)+(VALUE(22)/3600.)
93      IF(VALUE(22).GT.10) GO TO 94
          BINVA(I,62)=BINVA(I,62)+(VALUE(23)/3600.)
94      BINVA(I,42)=BINVA(I,42)+1
C      IF(VALUE(2).EQ.0)GO TO 750
C      IF(VALUE(22).GT.12.0)GO TO 750
C      IF(VALUE(23).GT.12.0)GO TO 750
          IF(VALUE(33).LT.0)GO TO 888
          VALUE(15)=0.
888      NORIN=VALUE(6)+VALUE(9)+VALUE(12)
          COPN=0.
          IF(NORIN.LT.27.0) GO TO 889
          COPN=(VALUE(29)-VALUE(15))/(VALUE(6)+VALUE(9)+VALUE(12))
889      IF(VALUE(33).LT.10.)GO TO 890
          VALUE(16)=0.
          VALUE(7)=0.
          VALUE(10)=0.
          VALUE(13)=0.
890      SHTOT=VALUE(15)+VALUE(16)
          IFTOT=VALUE(5)+VALUE(6)+VALUE(7)
          OFTOT=VALUE(8)+VALUE(9)+VALUE(10)
          COMTOT=VALUE(11)+VALUE(12)+VALUE(13)
          RTHR=(VALUE(22)+VALUE(23))/3600.
          IF(RTHR.LT.1)GO TO 891
          RTHR=1.
891      CCTOT=VALUE(17)*(1.-RTHR)
          KWACT=(IFTOT+OFTOT+COMTOT+CCTOT+SHTOT)/1000.
          KWTRIN=(VALUE(5)+VALUE(8)+VALUE(11))/1000.
          KWDEIN=(VALUE(7)+VALUE(10)+VALUE(13))/1000.
          TOTOUT=VALUE(28)+VALUE(29)+VALUE(30)
          IF(VALUE(22).GT.12.)GO TO 555
          COPSS=2.481+.0634*VALUE(33)
          GO TO 557
555      IF(VALUE(23).GT.12.)GO TO 556
          COPSS=2.267+.0488*VALUE(33)
          GO TO 557
556      COPSSH=2.267+.0488*VALUE(33)
          COPSSL=2.481+.0634*VALUE(33)
          COPSS=0.
          KWSS=0.
          IF((VALUE(23)+VALUE(22)).LT.20.0) GO TO 797
          COPSS=(VALUE(23)*COPSSL+VALUE(22)*COPSSH)/(VALUE(23)+
          *VALUE(22))
557      KWSS=(TOTOUT-VALUE(15))/(1000.*COPSS)+VALUE(15)/1000.
797      IF(COPN.EQ.0) GO TO 558
          BINVA(I,45)=KWACT-(KWTRIN-VALUE(28))/(1000.*COPN))+
          *BINVA(I,45)
          BINVA(I,46)=KWACT-(KWDEIN+VALUE(16)/1000.-VALUE(30)/
          *(1000.*COPN))+BINVA(I,46)
          BINVA(I,55)=(TOTOUT-VALUE(15))/(1000.*COPN)+VALUE(15)/
          *1000.+BINVA(I,55)

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558      BINVA(I,54)=KWSS+BINVA(I,54)
        IF(COPSS.EQ.0) GO TO 798
        BINVA(I,49)=KWSS-(KWTRIN-VALUE(28)/(1000.*COPSS))+
*BINVA(I,49)
        BINVA(I,50)=KWSS-(KWDEIN+VALUE(16)/1000.-VALUE(30)/
*(1000.*COPSS))+BINVA(I,50)
798      IF(VALUE(2).LT.16.0) GO TO 799
        BINVA(I,3)=BINVA(I,3)+1
        BINVA(I,40)=VALUE(33)+BINVA(I,40)
        BINVA(I,41)=VALUE(1)+BINVA(I,41)
        BINVA(I,4)=(VALUE(25)+VALUE(26))*(4./60.)+BINVA(I,4)
        BINVA(I,5)=BINVA(I,5)+(VALUE(22)+VALUE(23))/3600.-
*(VALUE(25)+VALUE(26))*(4./60.)
799      IF(VALUE(33).GE.10)GO TO 667
        BINVA(I,6)=BINVA(I,6)+VALUE(24)/3600.
667      BINVA(I,7)=BINVA(I,7)+VALUE(25)+VALUE(26)
        IF(VALUE(33).GE.10)GO TO 668
        BINVA(I,8)=BINVA(I,8)+VALUE(19)
668      BINVA(I,9)=BINVA(I,9)+(VALUE(5)+VALUE(8)+VALUE(11))/1000.
        BINVA(I,10)=BINVA(I,10)+(VALUE(6)+VALUE(9)+VALUE(12))/
*1000.
        IF(VALUE(33).GE.10)GO TO 669
        BINVA(I,11)=BINVA(I,11)+(VALUE(7)+VALUE(10)+VALUE(13))/1000.
669      BINVA(I,14)=BINVA(I,14)+VALUE(28)/1000.
        BINVA(I,15)=BINVA(I,15)+(VALUE(29))/1000.
        IF(VALUE(33).GE.10)GO TO 670
        BINVA(I,16)=BINVA(I,16)+VALUE(30)/1000.
670      IF (VALUE(33).GE.0)GO TO 666
        BINVA(I,18)=BINVA(I,18)+VALUE(15)/1000.
666      IF(VALUE(33).GE.10)GO TO 671
        BINVA(I,19)=BINVA(I,19)+VALUE(16)/1000.
671      BINVA(I,26)=BINVA(I,26)+VALUE(26)
        BINVA(I,27)=BINVA(I,27)+VALUE(25)
        IF(VALUE(23).EQ.0)GO TO 750
        BINVA(I,28)=BINVA(I,28)+(VALUE(15)+VALUE(16))/1000.
750      CONTINUE
13      CLOSE(UNIT=43)
        GO TO 800 843
        DO 8 I=1,11
        BINVA(I,43)=BINVA(I,4)+BINVA(I,5)+BINVA(I,6)
        BINVA(I,60)=BINVA(I,58)+BINVA(I,59)
        BINVA(I,63)=BINVA(I,61)+BINVA(I,62)
        IF(BINVA(I,42).EQ.0) GO TO 963
C      BINVA(I,12)=BINVA(I,44)*((BINVA(I,42)-BINVA(I,60))/
C      *BINVA(I,42))*BINVA(I,62)/BINVA(I,60)
C      BINVA(I,12)=BINVA(I,44)*((BINVA(I,42)-BINVA(I,60))/
C      *BINVA(I,42))*BINVA(I,61)/BINVA(I,60)
        BINVA(I,12)=BINVA(I,44)*((BINVA(I,42)-BINVA(I,43))/
*BINVA(I,42))
963      IF(BINVA(I,12).GE.0)GO TO 673
        BINVA(I,12)=0.

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673  BINVA(I,13)=BINVA(I,9)+BINVA(I,10)+BINVA(I,11)+BINVA(I,12)
      BINVA(I,17)=BINVA(I,14)+BINVA(I,15)+BINVA(I,16)
      BINVA(I,45)=BINVA(I,45)-BINVA(I,18)
      BINVA(I,46)=BINVA(I,46)-BINVA(I,18)
      BINVA(I,49)=BINVA(I,49)+BINVA(I,12)-BINVA(I,18)
      BINVA(I,50)=BINVA(I,50)+BINVA(I,12)-BINVA(I,18)
      BINVA(I,51)=BINVA(I,51)+BINVA(I,12)
      BINVA(I,53)=BINVA(I,13)+BINVA(I,18)+BINVA(I,19)
      BINVA(I,54)=BINVA(I,54)+BINVA(I,12)
      BINVA(I,55)=BINVA(I,55)+BINVA(I,12)
      BINVA(I,47)=BINVA(I,53)-BINVA(I,18)
      BINVA(I,48)=BINVA(I,53)-BINVA(I,12)-BINVA(I,18)
      BINVA(I,51)=BINVA(I,54)-BINVA(I,18)
      BINVA(I,52)=BINVA(I,54)-BINVA(I,12)-BINVA(I,18)
      BINVA(I,56)=BINVA(I,53)-BINVA(I,18)
      BINVA(I,57)=BINVA(I,54)-BINVA(I,18)
      IF(BINVA(I,53).EQ.0) GO TO 964
      BINVA(I,32)=(BINVA(I,56)-BINVA(I,45))/BINVA(I,56)*100.
      BINVA(I,34)=(BINVA(I,53)-BINVA(I,47))/BINVA(I,53)*100.
      BINVA(I,35)=(BINVA(I,56)-BINVA(I,48))/BINVA(I,56)*100.
964  IF(BINVA(I,54).EQ.0) GO TO 965
      BINVA(I,36)=(BINVA(I,57)-BINVA(I,49))/BINVA(I,57)*100.
      BINVA(I,38)=(BINVA(I,54)-BINVA(I,51))/BINVA(I,54)*100.
      BINVA(I,39)=(BINVA(I,57)-BINVA(I,52))/BINVA(I,57)*100.
965  IF(BINVA(I,3).EQ.0) GO TO 8
      BINVA(I,1)=BINVA(I,40)/BINVA(I,3)
      BINVA(I,2)=BINVA(I,41)/BINVA(I,3)
      IF(BINVA(I,4).EQ.0) GOTO 14
      BINVA(I,30)=BINVA(I,4)/(BINVA(I,4)+BINVA(I,5)+BINVA(I,6))
      **100.
      BINVA(I,20)=BINVA(I,14)/BINVA(I,9)
14   IF(BINVA(I,5).EQ.0) GOTO 16
      BINVA(I,21)=(BINVA(I,15)-BINVA(I,18))/BINVA(I,10)
      BINVA(I,23)=BINVA(I,15)/(BINVA(I,10)+BINVA(I,18))
16   IF(BINVA(I,6).EQ.0) GO TO 18
      BINVA(I,33)=(BINVA(I,56)-BINVA(I,46))/BINVA(I,56)*100.
      BINVA(I,37)=(BINVA(I,57)-BINVA(I,50))/BINVA(I,57)*100.
      BINVA(I,29)=BINVA(I,6)/(BINVA(I,4)+BINVA(I,5)+BINVA(I,6))
      **100.
      BINVA(I,24)=BINVA(I,16)/(BINVA(I,11)+BINVA(I,19))
18   IF((BINVA(I,4)+BINVA(I,5)+BINVA(I,6)).EQ.0) GO TO 8
      BINVA(I,22)=(BINVA(I,14)+BINVA(I,15)-BINVA(I,18))/
      *(BINVA(I,9)+BINVA(I,10)+BINVA(I,12))
      BINVA(I,25)=BINVA(I,17)/(BINVA(I,13)+BINVA(I,18)+BINVA(I,19))
      BINVA(I,31)=(BINVA(I,17)-BINVA(I,18))/(BINVA(I,13)+
      *BINVA(I,19))
      KWMTLN=BINVA(I,45)+KWMTLN
      KWMDLN=BINVA(I,46)+KWMDLN
      KWMSHL=BINVA(I,47)+KWMSHL
      KWMCCCL=BINVA(I,48)+KWMCCCL
      KWMTLS=BINVA(I,49)+KWMTLS

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      KWMDLS=BINVA(I,50)+KWMDLS
      KWMSHS=+BINVA(I,51)+KWMSHS
      KWMCCS=BINVA(I,52)+KWMCCS
      KWATOT=BINVA(I,53)+KWATOT
      KWANSH=BINVA(I,56)+KWANSH
      KWSSTO=BINVA(I,54)+KWSSTO
      KWSSNS=BINVA(I,57)+KWSSNS
8      CONTINUE
801     WRITE(45,846)
846     FORMAT(1H ,/)
      WRITE(45,5678)
5678    FORMAT(36X,'-25/-20 ','-20/-15 ','-15/-10 ','-10/-5 '
*, '-5/0 ',' 0/5 ',' 5/10 ',' 10/15 ',' 15/20 ',
*' 20/25 ',' 25/30 ')
      DO 3 L=1,57
      READ(47,847)(A(J),J=1,34)
847     FORMAT(34A1)
      WRITE(45,845)(A(J),J=1,34),(BINVA(M,L),M=1,11)
845     FORMAT(1X,34(A1),11(F8.3))
3      CONTINUE
      DTRN=(KWANSH-KWMTLN)/KWANSH*100.
      DDEFN=(KWANSH-KWMDLN)/KWANSH*100.
      DSHN=(KWATOT-KWMSHL)/KWATOT*100.
      DCCN=(KWANSH-KWMCCL)/KWANSH*100.
      DTRSS=(KWSSNS-KWMTLS)/KWSSNS*100.
      DDESS=(KWSSNS-KWMDLS)/KWSSNS*100.
      DSHSS=(KWSSTO-KWMSHS)/KWSSTO*100.
      DCCSS=(KWSSNS-KWMCCS)/KWSSNS*100.
      WRITE(45,1050)
1050    FORMAT(1X)
      WRITE(45,1055)
1055    FORMAT(' NORMAL DEGRADATIONS FACTORS:')
      WRITE(45,1060) DTRN,DDEFN,DSHN,DCCN
1060    FORMAT(2X,'TRANSIENT=',F4.1,4X,'DEFROST=',F4.1,4X,
*'STRIP HEAT=',F4.1,4X,'CRANKCASE=',F4.1)
      WRITE(45,1080)
1080    FORMAT(1X)
      WRITE(45,1090)
1090    FORMAT(' STEADY STATE DEGRADATION FACTORS:')
      WRITE(45,1100) DTRSS,DDESS,DSHSS,DCCSS
1100    FORMAT(2X,'TRANSIENT=',F4.1,4X,'DEFROST=',F4.1,4X,
*'STRIP HEAT=',F4.1,4X,'CRANKCASE=',F4.1)
      CLOSE(UNIT=45)
      CLOSE(UNIT=47)
      STOP
      END

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A.8 Dual-Speed Mode's (Low Hours Only) Heating Analysis Computer Program

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REAL VALUE(40),BINVA(11,63)
REAL COPN,IFTOT,OFTOT,COMTOT,SHOT,RTHR,CCTOT,NORIN
REAL KWACT,KWDEIN,KWTRIN,TOTOUT,KWSS,COPSS,COPSSL,COPSSH
REAL KWMTLN,KWMDLN,KWMSHL,KWMCCL,KWATOT,KWANSH,LSSH
REAL KWMTLS,KWMDLS,KWMSHS,KWMCSS,KWSSSTO,KWSSNS
DIMENSION A(53)
INTEGER IDAYS
OPEN(UNIT=45,FILE='SILVER.DAT')
101 OPEN(UNIT=44,FILE='BIN.DAT')
WRITE(5,327)
327 FORMAT(' WHAT IS THE INPUT FILE')
READ(5,328)FNAM
328 FORMAT(A6)
WRITE(5,329)FNAM
329 FORMAT(' FOR THE WEEK ',A6,' HOW MANY DAYS ARE THERE')
READ(5,330)DAYS
330 FORMAT(F10.0)
IF(DAYS.GE.43)GOTO 843
IDAYS=DAYS
IHOURS=IDAYS*24
800 READ(44,844)TLOW,THIGH,I
844 FORMAT(2F10.4,I2)
IF(TLOW.EQ.843)CLOSE(UNIT=44)
IF(TLOW.EQ.843)GOTO 101
OPEN(UNIT=43,FILE=FNAM)
OPEN(UNIT=47,FILE='NAMBI1.DAT')
DO 750 II=1,IHOURS
READ(43,250)(VALUE(J),J=1,40)
250 FORMAT(8F10.4)
DO 270 K=1,40
IF(VALUE(K).EQ.99999)GOTO 750
270 CONTINUE
IF(VALUE(33).LT.-30.0)WRITE(5,78)
78 FORMAT('LOWER THAN -30 C')
IF(VALUE(33).GE.30.0)WRITE(5,79)
79 FORMAT('EQUAL OR GREATER THAN 30 C')
IF((VALUE(33).LT.TLOW).OR.(VALUE(33).GE.THIGH))
*GO TO 750
LSSH=0.
IF(VALUE(23).LT.27.) GO TO 95
LSSH=VALUE(15)
95 IF(LSSH.GT.100) WRITE(5,1313) FNAM,II
1313 FORMAT(' HEY BUCKO, FNAM=',A5,' FOR II=',I3)
IF(LSSH.GT.100) GO TO 750
BINVA(I,44)=BINVA(I,44)+(VALUE(17)/1000.)
BINVA(I,58)=BINVA(I,58)+(VALUE(22)/3600.)
BINVA(I,59)=BINVA(I,59)+(VALUE(23)/3600.)

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IF(VALUE(23).GT.10) GO TO 93
    BINVA(I,61)=BINVA(I,61)+(VALUE(22)/3600.)
93  IF(VALUE(22).GT.10) GO TO 94
    BINVA(I,62)=BINVA(I,62)+(VALUE(23)/3600.)
94  BINVA(I,42)=BINVA(I,42)+1
C   IF(VALUE(2).EQ.0)GO TO 750
    IF(VALUE(22).GT.12.0)GO TO 750
C   IF(VALUE(23).GT.12.0)GO TO 750
    IF(VALUE(33).LT.0)GO TO 888
    VALUE(15)=0.
888  NORIN=VALUE(6)+VALUE(9)+VALUE(12)
    COPN=0.
    IF(NORIN.LT.27.0) GO TO 889
    COPN=(VALUE(29)-VALUE(15))/(VALUE(6)+VALUE(9)+VALUE(12))
889  IF(VALUE(33).LT.10.)GO TO 890
    VALUE(16)=0.
    VALUE(7)=0.
    VALUE(10)=0.
    VALUE(13)=0.
890  SHTOT=VALUE(15)+VALUE(16)
    IFTOT=VALUE(5)+VALUE(6)+VALUE(7)
    OFTOT=VALUE(8)+VALUE(9)+VALUE(10)
    COMTOT=VALUE(11)+VALUE(12)+VALUE(13)
    RTHR=(VALUE(22)+VALUE(23))/3600.
    IF(RTHR.LT.1)GO TO 891
    RTHR=1.
891  CCTOT=VALUE(17)*(1.-RTHR)
    KWACT=(IFTOT+OFTOT+COMTOT+CCTOT+SHTOT)/1000.
    KWTRIN=(VALUE(5)+VALUE(8)+VALUE(11))/1000.
    KWDEIN=(VALUE(7)+VALUE(10)+VALUE(13))/1000.
    TOTOUT=VALUE(28)+VALUE(29)+VALUE(30)
    IF(VALUE(22).GT.12.)GO TO 555
    COPSS=2.481+.0634*VALUE(33)
    GO TO 557
555  IF(VALUE(23).GT.12.)GO TO 556
    COPSS=2.267+.0488*VALUE(33)
    GO TO 557
556  COPSSH=2.267+.0488*VALUE(33)
    COPSSL=2.481+.0634*VALUE(33)
    COPSS=0.
    KWSS=0.
    IF((VALUE(23)+VALUE(22)).LT.20.0) GO TO 797
    COPSS=(VALUE(23)*COPSSL+VALUE(22)*COPSSH)/(VALUE(23)+
*VALUE(22))
557  KWSS=(TOTOUT-VALUE(15))/(1000.*COPSS)+VALUE(15)/1000.
797  IF(COPN.EQ.0) GO TO 558
    BINVA(I,45)=KWACT-(KWTRIN-VALUE(28)/(1000.*COPN))+
*BINVA(I,45)
    BINVA(I,46)=KWACT-(KWDEIN+VALUE(16)/1000.-VALUE(30)/
*(1000.*COPN))+BINVA(I,46)
    BINVA(I,55)=(TOTOUT-VALUE(15))/(1000.*COPN)+VALUE(15)/

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*1000.+BINVA(I,55)
558     BINVA(I,54)=KWSS+BINVA(I,54)
        IF(COPSS.EQ.0) GO TO 798
        BINVA(I,49)=KWSS-(KWTRIN-VALUE(28)/(1000.*COPSS))+
*BINVA(I,49)
        BINVA(I,50)=KWSS-(KWDEIN+VALUE(16)/1000.-VALUE(30)/
*(1000.*COPSS))+BINVA(I,50)
798     IF(VALUE(2).LT.16.0) GO TO 799
        BINVA(I,3)=BINVA(I,3)+1
        BINVA(I,40)=VALUE(33)+BINVA(I,40)
        BINVA(I,41)=VALUE(1)+BINVA(I,41)
        BINVA(I,4)=(VALUE(25)+VALUE(26))*(4./60.)+BINVA(I,4)
        BINVA(I,5)=BINVA(I,5)+(VALUE(22)+VALUE(23))/3600.-
*(VALUE(25)+VALUE(26))*(4./60.)
799     IF(VALUE(33).GE.10)GO TO 667
        BINVA(I,6)=BINVA(I,6)+VALUE(24)/3600.
667     BINVA(I,7)=BINVA(I,7)+VALUE(25)+VALUE(26)
        IF(VALUE(33).GE.10)GO TO 668
        BINVA(I,8)=BINVA(I,8)+VALUE(19)
668     BINVA(I,9)=BINVA(I,9)+(VALUE(5)+VALUE(8)+VALUE(11))/1000.
        BINVA(I,10)=BINVA(I,10)+(VALUE(6)+VALUE(9)+VALUE(12))/
*1000.
        IF(VALUE(33).GE.10)GO TO 669
        BINVA(I,11)=BINVA(I,11)+(VALUE(7)+VALUE(10)+VALUE(13))/1000.
669     BINVA(I,14)=BINVA(I,14)+VALUE(28)/1000.
        BINVA(I,15)=BINVA(I,15)+(VALUE(29))/1000.
        IF(VALUE(33).GE.10)GO TO 670
        BINVA(I,16)=BINVA(I,16)+VALUE(30)/1000.
670     IF (VALUE(33).GE.0)GO TO 666
        BINVA(I,18)=BINVA(I,18)+VALUE(15)/1000.
666     IF(VALUE(33).GE.10)GO TO 671
        BINVA(I,19)=BINVA(I,19)+VALUE(16)/1000.
671     BINVA(I,26)=BINVA(I,26)+VALUE(26)
        BINVA(I,27)=BINVA(I,27)+VALUE(25)
        IF(VALUE(23).EQ.0)GO TO 750
        BINVA(I,28)=BINVA(I,28)+(VALUE(15)+VALUE(16))/1000.
750     CONTINUE
13      CLOSE(UNIT=43)
        GO TO 800 843
        DO 8 I=1,11
        BINVA(I,43)=BINVA(I,4)+BINVA(I,5)+BINVA(I,6)
        BINVA(I,60)=BINVA(I,58)+BINVA(I,59)
        BINVA(I,63)=BINVA(I,61)+BINVA(I,62)
        IF(BINVA(I,42).EQ.0) GO TO 963
        BINVA(I,12)=BINVA(I,44)*((BINVA(I,42)-BINVA(I,60)))/
*BINVA(I,42))*BINVA(I,62)/BINVA(I,60)
C       BINVA(I,12)=BINVA(I,44)*((BINVA(I,42)-BINVA(I,60)))/
C       *BINVA(I,42))*BINVA(I,61)/BINVA(I,60)
C       BINVA(I,12)=BINVA(I,44)*((BINVA(I,42)-BINVA(I,43)))/
C       *BINVA(I,42))
963     IF(BINVA(I,12).GE.0)GO TO 673

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        BINVA(I,12)=0.
673  BINVA(I,13)=BINVA(I,9)+BINVA(I,10)+BINVA(I,11)+BINVA(I,12)
        BINVA(I,17)=BINVA(I,14)+BINVA(I,15)+BINVA(I,16)
        BINVA(I,45)=BINVA(I,45)-BINVA(I,18)
        BINVA(I,46)=BINVA(I,46)-BINVA(I,18)
        BINVA(I,49)=BINVA(I,49)+BINVA(I,12)-BINVA(I,18)
        BINVA(I,50)=BINVA(I,50)+BINVA(I,12)-BINVA(I,18)
        BINVA(I,51)=BINVA(I,51)+BINVA(I,12)
        BINVA(I,53)=BINVA(I,13)+BINVA(I,18)+BINVA(I,19)
        BINVA(I,54)=BINVA(I,54)+BINVA(I,12)
        BINVA(I,55)=BINVA(I,55)+BINVA(I,12)
        BINVA(I,47)=BINVA(I,53)-BINVA(I,18)
        BINVA(I,48)=BINVA(I,53)-BINVA(I,12)-BINVA(I,18)
        BINVA(I,51)=BINVA(I,54)-BINVA(I,18)
        BINVA(I,52)=BINVA(I,54)-BINVA(I,12)-BINVA(I,18)
        BINVA(I,56)=BINVA(I,53)-BINVA(I,18)
        BINVA(I,57)=BINVA(I,54)-BINVA(I,18)
        IF(BINVA(I,53).EQ.0) GO TO 964
        BINVA(I,32)=(BINVA(I,56)-BINVA(I,45))/BINVA(I,56)*100.
        BINVA(I,34)=(BINVA(I,53)-BINVA(I,47))/BINVA(I,53)*100.
        BINVA(I,35)=(BINVA(I,56)-BINVA(I,48))/BINVA(I,56)*100.
964  IF(BINVA(I,54).EQ.0) GO TO 965
        BINVA(I,36)=(BINVA(I,57)-BINVA(I,49))/BINVA(I,57)*100.
        BINVA(I,38)=(BINVA(I,54)-BINVA(I,51))/BINVA(I,54)*100.
        BINVA(I,39)=(BINVA(I,57)-BINVA(I,52))/BINVA(I,57)*100.
965  IF(BINVA(I,3).EQ.0) GO TO 8
        BINVA(I,1)=BINVA(I,40)/BINVA(I,3)
        BINVA(I,2)=BINVA(I,41)/BINVA(I,3)
        IF(BINVA(I,4).EQ.0) GOTO 14
        BINVA(I,30)=BINVA(I,4)/(BINVA(I,4)+BINVA(I,5)+BINVA(I,6))
        **100.
        BINVA(I,20)=BINVA(I,14)/BINVA(I,9)
14   IF(BINVA(I,5).EQ.0) GOTO 16
        BINVA(I,21)=(BINVA(I,15)-BINVA(I,18))/BINVA(I,10)
        BINVA(I,23)=BINVA(I,15)/(BINVA(I,10)+BINVA(I,18))
16   IF(BINVA(I,6).EQ.0) GO TO 18
        BINVA(I,33)=(BINVA(I,56)-BINVA(I,46))/BINVA(I,56)*100.
        BINVA(I,37)=(BINVA(I,57)-BINVA(I,50))/BINVA(I,57)*100.
        BINVA(I,29)=BINVA(I,6)/(BINVA(I,4)+BINVA(I,5)+BINVA(I,6))
        **100.
        BINVA(I,24)=BINVA(I,16)/(BINVA(I,11)+BINVA(I,19))
18   IF((BINVA(I,4)+BINVA(I,5)+BINVA(I,6)).EQ.0) GO TO 8
        BINVA(I,22)=(BINVA(I,14)+BINVA(I,15)-BINVA(I,18))/
        *(BINVA(I,9)+BINVA(I,10)+BINVA(I,12))
        BINVA(I,25)=BINVA(I,17)/(BINVA(I,13)+BINVA(I,18)+BINVA(I,19))
        BINVA(I,31)=(BINVA(I,17)-BINVA(I,18))/(BINVA(I,13)+
        *BINVA(I,19))
        KWMTLN=BINVA(I,45)+KWMTLN
        KWMDLN=BINVA(I,46)+KWMDLN
        KWMSHL=BINVA(I,47)+KWMSHL
        KWMCCCL=BINVA(I,48)+KWMCCCL

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      KWMTLS=BINVA(I,49)+KWMTLS
      KWMDLS=BINVA(I,50)+KWMDLS
      KWMSHS=+BINVA(I,51)+KWMSHS
      KWMCCS=BINVA(I,52)+KWMCCS
      KWATOT=BINVA(I,53)+KWATOT
      KWANSH=BINVA(I,56)+KWANSH
      KWSSTO=BINVA(I,54)+KWSSTO
      KWSSNS=BINVA(I,57)+KWSSNS
8      CONTINUE
801     WRITE(45,846).
846     FORMAT(1H ,/)
      WRITE(45,5678)
5678    FORMAT(36X,'-25/-20 ','-20/-15 ','-15/-10 ','-10/-5 '
*, '-5/0 ',' 0/5 ',' 5/10 ',' 10/15 ',' 15/20 ',
*, ' 20/25 ',' 25/30 ')
      DO 3 L=1,57
      READ(47,847)(A(J),J=1,34)
847     FORMAT(34A1)
      WRITE(45,845)(A(J),J=1,34),(BINVA(M,L),M=1,11)
845     FORMAT(1X,34(A1),11(F8.3))
3      CONTINUE
      DTRN=(KWANSH-KWMTLN)/KWANSH*100.
      DDEFN=(KWANSH-KWMDLN)/KWANSH*100.
      DSHN=(KWATOT-KWMSHL)/KWATOT*100.
      DCCN=(KWANSH-KWMCCL)/KWANSH*100.
      DTRSS=(KWSSNS-KWMTLS)/KWSSNS*100.
      DDESS=(KWSSNS-KWMDLS)/KWSSNS*100.
      DSHSS=(KWSSTO-KWMSHS)/KWSSTO*100.
      DCCSS=(KWSSNS-KWMCCS)/KWSSNS*100.
      WRITE(45,1050)
1050    FORMAT(1X)
      WRITE(45,1055)
1055    FORMAT(' NORMAL DEGRADATIONS FACTORS:')
      WRITE(45,1060) DTRN,DDEFN,DSHN,DCCN
1060    FORMAT(2X,'TRANSIENT=',F4.1,4X,'DEFROST=',F4.1,4X,
*, 'STRIP HEAT=',F4.1,4X,'CRANKCASE=',F4.1)
      WRITE(45,1080)
1080    FORMAT(1X)
      WRITE(45,1090)
1090    FORMAT(' STEADY STATE DEGRADATION FACTORS:')
      WRITE(45,1100) DTRSS,DDESS,DSHSS,DCCSS
1100    FORMAT(2X,'TRANSIENT=',F4.1,4X,'DEFROST=',F4.1,4X,
*, 'STRIP HEAT=',F4.1,4X,'CRANKCASE=',F4.1)
      CLOSE(UNIT=45)
      CLOSE(UNIT=47)
      STOP
      END

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A.9 Dual-Speed Mode's (High Hours Only) Heating Analysis Computer Program

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REAL VALUE(40),BINVA(11,63)
REAL COPN,IFTOT,OFTOT,COMTOT,SHTOT,RTHR,CCTOT,NORIN
REAL KWACT,KWDEIN,KWTRIN,TOTOUT,KWSS,COPSS,COPSSL,COPSSH
REAL KWMTLN,KWMDLN,KWMSHL,KWMCCL,KWATOT,KWANSH,LSSH
REAL KWMTLS,KWMDLS,KWMSHS,KWMCSS,KWSSTO,KWSSENS
DIMENSION A(53)
INTEGER IDAYS
OPEN(UNIT=45,FILE='SILVER.DAT')
101 OPEN(UNIT=44,FILE='BIN.DAT')
WRITE(5,327)
327 FORMAT(' WHAT IS THE INPUT FILE')
READ(5,328)FNAM
328 FORMAT(A6)
WRITE(5,329)FNAM
329 FORMAT(' FOR THE WEEK ',A6,' HOW MANY DAYS ARE THERE')
READ(5,330)DAYS
330 FORMAT(F10.0)
IF(DAYS.GE.43)GOTO 843
IDAYS=DAYS
IHOURLS=IDAYS*24
800 READ(44,844)TLOW,THIGH,I
844 FORMAT(2F10.4,I2)
IF(TLOW.EQ.843)CLOSE(UNIT=44)
IF(TLOW.EQ.843)GOTO 101
OPEN(UNIT=43,FILE=FNAM)
OPEN(UNIT=47,FILE='NAMBI1.DAT')
DO 750 II=1,IHOURLS
READ(43,250)(VALUE(J),J=1,40)
250 FORMAT(8F10.4)
DO 270 K=1,40
IF(VALUE(K).EQ.99999)GOTO 750
270 CONTINUE
IF(VALUE(33).LT.-30.0)WRITE(5,78)
78 FORMAT('LOWER THAN -30 C')
IF(VALUE(33).GE.30.0)WRITE(5,79)
79 FORMAT('EQUAL OR GREATER THAN 30 C')
IF((VALUE(33).LT. TLOW) .OR. (VALUE(33).GE. THIGH))
*GO TO 750
LSSH=0.
IF(VALUE(23).LT.27.) GO TO 95
LSSH=VALUE(15)
95 IF(LSSH.GT.100) WRITE(5,1313) FNAM,II
1313 FORMAT(' HEY BUCKO, FNAM=',A5,' FOR II=',I3)
IF(LSSH.GT.100) GO TO 750
BINVA(I,44)=BINVA(I,44)+(VALUE(17)/1000.)
BINVA(I,58)=BINVA(I,58)+(VALUE(22)/3600.)
BINVA(I,59)=BINVA(I,59)+(VALUE(23)/3600.)

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IF(VALUE(23).GT.10) GO TO 93
  BINVA(I,61)=BINVA(I,61)+(VALUE(22)/3600.)
93  IF(VALUE(22).GT.10) GO TO 94
    BINVA(I,62)=BINVA(I,62)+(VALUE(23)/3600.)
94  BINVA(I,42)=BINVA(I,42)+1
C   IF(VALUE(2).EQ.0)GO TO 750
C   IF(VALUE(22).GT.12.0)GO TO 750
    IF(VALUE(23).GT.12.0)GO TO 750
    IF(VALUE(33).LT.0)GO TO 888
    VALUE(15)=0.
888  NORIN=VALUE(6)+VALUE(9)+VALUE(12)
    COPN=0.
    IF(NORIN.LT.27.0) GO TO 889
    COPN=(VALUE(29)-VALUE(15))/(VALUE(6)+VALUE(9)+VALUE(12))
889  IF(VALUE(33).LT.10.)GO TO 890
    VALUE(16)=0.
    VALUE(7)=0.
    VALUE(10)=0.
    VALUE(13)=0.
890  SHTOT=VALUE(15)+VALUE(16)
    IFTOT=VALUE(5)+VALUE(6)+VALUE(7)
    OFTOT=VALUE(8)+VALUE(9)+VALUE(10)
    COMTOT=VALUE(11)+VALUE(12)+VALUE(13)
    RTHR=(VALUE(22)+VALUE(23))/3600.
    IF(RTHR.LT.1)GO TO 891
    RTHR=1.
891  CCTOT=VALUE(17)*(1.-RTHR)
    KWACT=(IFTOT+OFTOT+COMTOT+CCTOT+SHTOT)/1000.
    KWTRIN=(VALUE(5)+VALUE(8)+VALUE(11))/1000.
    KWDEIN=(VALUE(7)+VALUE(10)+VALUE(13))/1000.
    TOTOUT=VALUE(28)+VALUE(29)+VALUE(30)
    IF(VALUE(22).GT.12.)GO TO 555
    COPSS=2.481+.0634*VALUE(33)
    GO TO 557
555  IF(VALUE(23).GT.12.)GO TO 556
    COPSS=2.267+.0488*VALUE(33)
    GO TO 557
556  COPSSH=2.267+.0488*VALUE(33)
    COPSSL=2.481+.0634*VALUE(33)
    COPSS=0.
    KWSS=0.
    IF((VALUE(23)+VALUE(22)).LT.20.0) GO TO 797
    COPSS=(VALUE(23)*COPSSL+VALUE(22)*COPSSH)/(VALUE(23)+
*VALUE(22))
557  KWSS=(TOTOUT-VALUE(15))/(1000.*COPSS)+VALUE(15)/1000.
797  IF(COPN.EQ.0) GO TO 558
    BINVA(I,45)=KWACT-(KWTRIN-VALUE(28))/(1000.*COPN))+
*BINVA(I,45)
    BINVA(I,46)=KWACT-(KWDEIN+VALUE(16)/1000.-VALUE(30)/
*(1000.*COPN))+BINVA(I,46)
    BINVA(I,55)=(TOTOUT-VALUE(15))/(1000.*COPN)+VALUE(15)/

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*1000.+BINVA(I,55)
558   BINVA(I,54)=KWSS+BINVA(I,54)
      IF(COPSS.EQ.0) GO TO 798
      BINVA(I,49)=KWSS-(KWTRIN-VALUE(28)/(1000.*COPSS))+
*BINVA(I,49)
      BINVA(I,50)=KWSS-(KWDEIN+VALUE(16)/1000.-VALUE(30)/
*(1000.*COPSS))+BINVA(I,50)
798   IF(VALUE(2).LT.16.0) GO TO 799
      BINVA(I,3)=BINVA(I,3)+1
      BINVA(I,40)=VALUE(33)+BINVA(I,40)
      BINVA(I,41)=VALUE(1)+BINVA(I,41)
      BINVA(I,4)=(VALUE(25)+VALUE(26))*(4./60.)+BINVA(I,4)
      BINVA(I,5)=BINVA(I,5)+(VALUE(22)+VALUE(23))/3600.-
*(VALUE(25)+VALUE(26))*(4./60.)
799   IF(VALUE(33).GE.10)GO TO 667
      BINVA(I,6)=BINVA(I,6)+VALUE(24)/3600.
667   BINVA(I,7)=BINVA(I,7)+VALUE(25)+VALUE(26)
      IF(VALUE(33).GE.10)GO TO 668
      BINVA(I,8)=BINVA(I,8)+VALUE(19)
668   BINVA(I,9)=BINVA(I,9)+(VALUE(5)+VALUE(8)+VALUE(11))/1000.
      BINVA(I,10)=BINVA(I,10)+(VALUE(6)+VALUE(9)+VALUE(12))/
*1000.
      IF(VALUE(33).GE.10)GO TO 669
      BINVA(I,11)=BINVA(I,11)+(VALUE(7)+VALUE(10)+VALUE(13))/1000.
669   BINVA(I,14)=BINVA(I,14)+VALUE(28)/1000.
      BINVA(I,15)=BINVA(I,15)+(VALUE(29))/1000.
      IF(VALUE(33).GE.10)GO TO 670
      BINVA(I,16)=BINVA(I,16)+VALUE(30)/1000.
670   IF (VALUE(33).GE.0)GO TO 666
      BINVA(I,18)=BINVA(I,18)+VALUE(15)/1000.
666   IF(VALUE(33).GE.10)GO TO 671
      BINVA(I,19)=BINVA(I,19)+VALUE(16)/1000.
671   BINVA(I,26)=BINVA(I,26)+VALUE(26)
      BINVA(I,27)=BINVA(I,27)+VALUE(25)
      IF(VALUE(23).EQ.0)GO TO 750
      BINVA(I,28)=BINVA(I,28)+(VALUE(15)+VALUE(16))/1000.
750   CONTINUE
13    CLOSE(UNIT=43)
      GO TO 800 843
      DO 8 I=1,11
      BINVA(I,43)=BINVA(I,4)+BINVA(I,5)+BINVA(I,6)
      BINVA(I,60)=BINVA(I,58)+BINVA(I,59)
      BINVA(I,63)=BINVA(I,61)+BINVA(I,62)
      IF(BINVA(I,42).EQ.0) GO TO 963
C     BINVA(I,12)=BINVA(I,44)*((BINVA(I,42)-BINVA(I,60)))/
C     *BINVA(I,42))*BINVA(I,62)/BINVA(I,60)
      BINVA(I,12)=BINVA(I,44)*((BINVA(I,42)-BINVA(I,60)))/
*BINVA(I,42))*BINVA(I,61)/BINVA(I,60)
C     BINVA(I,12)=BINVA(I,44)*((BINVA(I,42)-BINVA(I,43)))/
C     *BINVA(I,42))
963   IF(BINVA(I,12).GE.0)GO TO 673

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        BINVA(I,12)=0.
673  BINVA(I,13)=BINVA(I,9)+BINVA(I,10)+BINVA(I,11)+BINVA(I,12)
      BINVA(I,17)=BINVA(I,14)+BINVA(I,15)+BINVA(I,16)
      BINVA(I,45)=BINVA(I,45)-BINVA(I,18)
      BINVA(I,46)=BINVA(I,46)-BINVA(I,18)
      BINVA(I,49)=BINVA(I,49)+BINVA(I,12)-BINVA(I,18)
      BINVA(I,50)=BINVA(I,50)+BINVA(I,12)-BINVA(I,18)
      BINVA(I,51)=BINVA(I,51)+BINVA(I,12)
      BINVA(I,53)=BINVA(I,13)+BINVA(I,18)+BINVA(I,19)
      BINVA(I,54)=BINVA(I,54)+BINVA(I,12)
      BINVA(I,55)=BINVA(I,55)+BINVA(I,12)
      BINVA(I,47)=BINVA(I,53)-BINVA(I,18)
      BINVA(I,48)=BINVA(I,53)-BINVA(I,12)-BINVA(I,18)
      BINVA(I,51)=BINVA(I,54)-BINVA(I,18)
      BINVA(I,52)=BINVA(I,54)-BINVA(I,12)-BINVA(I,18)
      BINVA(I,56)=BINVA(I,53)-BINVA(I,18)
      BINVA(I,57)=BINVA(I,54)-BINVA(I,18)
      IF(BINVA(I,53).EQ.0) GO TO 964
      BINVA(I,32)=(BINVA(I,56)-BINVA(I,45))/BINVA(I,56)*100.
      BINVA(I,34)=(BINVA(I,53)-BINVA(I,47))/BINVA(I,53)*100.
      BINVA(I,35)=(BINVA(I,56)-BINVA(I,48))/BINVA(I,56)*100.
964  IF(BINVA(I,54).EQ.0) GO TO 965
      BINVA(I,36)=(BINVA(I,57)-BINVA(I,49))/BINVA(I,57)*100.
      BINVA(I,38)=(BINVA(I,54)-BINVA(I,51))/BINVA(I,54)*100.
      BINVA(I,39)=(BINVA(I,57)-BINVA(I,52))/BINVA(I,57)*100.
965  IF(BINVA(I,3).EQ.0) GO TO 8
      BINVA(I,1)=BINVA(I,40)/BINVA(I,3)
      BINVA(I,2)=BINVA(I,41)/BINVA(I,3)
      IF(BINVA(I,4).EQ.0) GO TO 14
      BINVA(I,30)=BINVA(I,4)/(BINVA(I,4)+BINVA(I,5)+BINVA(I,6))
      **100.
      BINVA(I,20)=BINVA(I,14)/BINVA(I,9)
14   IF(BINVA(I,5).EQ.0) GOTO 16
      BINVA(I,21)=(BINVA(I,15)-BINVA(I,18))/BINVA(I,10)
      BINVA(I,23)=BINVA(I,15)/(BINVA(I,10)+BINVA(I,18))
16   IF(BINVA(I,6).EQ.0) GO TO 18
      BINVA(I,33)=(BINVA(I,56)-BINVA(I,46))/BINVA(I,56)*100.
      BINVA(I,37)=(BINVA(I,57)-BINVA(I,50))/BINVA(I,57)*100.
      BINVA(I,29)=BINVA(I,6)/(BINVA(I,4)+BINVA(I,5)+BINVA(I,6))
      **100.
      BINVA(I,24)=BINVA(I,16)/(BINVA(I,11)+BINVA(I,19))
18   IF((BINVA(I,4)+BINVA(I,5)+BINVA(I,6)).EQ.0) GO TO 8
      BINVA(I,22)=(BINVA(I,14)+BINVA(I,15)-BINVA(I,18))/
      *(BINVA(I,9)+BINVA(I,10)+BINVA(I,12))
      BINVA(I,25)=BINVA(I,17)/(BINVA(I,13)+BINVA(I,18)+BINVA(I,19))
      BINVA(I,31)=(BINVA(I,17)-BINVA(I,18))/(BINVA(I,13)+
      *BINVA(I,19))
      KWMTLN=BINVA(I,45)+KWMTLN
      KWMDLN=BINVA(I,46)+KWMDLN
      KWMSHL=BINVA(I,47)+KWMSHL
      KWMCCCL=BINVA(I,48)+KWMCCCL

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```

      KWMTLS=BINVA(I,49)+KWMTLS
      KWMDLS=BINVA(I,50)+KWMDLS
      KWMSHS=+BINVA(I,51)+KWMSHS
      KWMCCS=BINVA(I,52)+KWMCCS
      KWATOT=BINVA(I,53)+KWATOT
      KWANSH=BINVA(I,56)+KWANSH
      KWSSTO=BINVA(I,54)+KWSSTO
      KWSSNS=BINVA(I,57)+KWSSNS
8      CONTINUE
801     WRITE(45,846)
846     FORMAT(1H ,/)
      WRITE(45,5678)
5678    FORMAT(36X,'-25/-20 ','-20/-15 ','-15/-10 ','-10/-5 '
*, '-5/0 ',' 0/5 ',' 5/10 ',' 10/15 ',' 15/20 ',
*' 20/25 ',' 25/30 ')
      DO 3 L=1,57
      READ(47,847)(A(J),J=1,34)
847     FORMAT(34A1)
      WRITE(45,845)(A(J),J=1,34),(BINVA(M,L),M=1,11)
845     FORMAT(1X,34(A1),11(F8.3))
3      CONTINUE
      DTRN=(KWANSH-KWMTLN)/KWANSH*100.
      DDEFN=(KWANSH-KWMDLN)/KWANSH*100.
      DSHN=(KWATOT-KWMSHL)/KWATOT*100.
      DCCN=(KWANSH-KWMCCS)/KWANSH*100.
      DTRSS=(KWSSNS-KWMTLS)/KWSSNS*100.
      DDESS=(KWSSNS-KWMDLS)/KWSSNS*100.
      DSHSS=(KWSSTO-KWMSHS)/KWSSTO*100.
      DCCSS=(KWSSNS-KWMCCS)/KWSSNS*100.
      WRITE(45,1050)
1050    FORMAT(1X)
      WRITE(45,1055)
1055    FORMAT(' NORMAL DEGRADATIONS FACTORS:')
      WRITE(45,1060) DTRN,DDEFN,DSHN,DCCN
1060    FORMAT(2X,'TRANSIENT=',F4.1,4X,'DEFROST=',F4.1,4X,
*'STRIP HEAT=',F4.1,4X,'CRANKCASE=',F4.1)
      WRITE(45,1080)
1080    FORMAT(1X)
      WRITE(45,1090)
1090    FORMAT(' STEADY STATE DEGRADATION FACTORS:')
      WRITE(45,1100) DTRSS,DDESS,DSHSS,DCCSS
1100    FORMAT(2X,'TRANSIENT=',F4.1,4X,'DEFROST=',F4.1,4X,
*'STRIP HEAT=',F4.1,4X,'CRANKCASE=',F4.1)
      CLOSE(UNIT=45)
      CLOSE(UNIT=47)
      STOP
      END

```

A.10 Heating Bin Value Descriptions

BINVA(I,1) Average Bin Dry Bulb Temperature (°C)
= (Σ outside dry bulb temperature) / (# of hours in bin)

BINVA(I,2) Average Bin Relative Humidity (%)
= (Σ outdoor relative humidity) / (# of hours in bin)

BINVA(I,3) # of Operating Hours in Bin

BINVA(I,4) Transient Operating Time (hr)

BINVA(I,5) Normal Operating Time (hr)

BINVA(I,6) Defrost Operating Time (hr)

BINVA(I,7) # of Start-up Cycles

BINVA(I,8) # of Defrost Cycles

BINVA(I,9) Transient Input Energy (Kw-hr)
= indoor fan transient + outdoor fan transient
+ compressor transient

BINVA(I,10) Normal Input Energy (Kw-hr)
= indoor fan normal + outdoor fan normal + compressor normal

BINVA(I,11) Defrost Input Energy (Kw-hr)
= indoor fan defrost + outdoor fan defrost + compressor defrost

BINVA(I,12) Total Off-Cycle Crankcase Input (Kw-hr)
= crankcase input (on + off-cycle) * (total bin hour count - total runtime) / (total bin hour count)

BINVA(I,13) Total Energy Input (Kw-hr)
= transient + normal + defrost + off-cycle inputs (exclusive of I²r)

BINVA(I,14) Transient Output Energy (Kw-hr)
= transient heat flow to airstream

BINVA(I,15) Normal Output Energy (Kw-hr)
= normal heat flow to airstream

BINVA(I,16) Defrost Output Energy (Kw-hr)
= defrost heat flow to airstream

BINVA(I,17) Total Output Energy (Kw-hr)
= transient + normal + defrost heat flows to airstream

BINVA(I,18) Normal Strip Heat (Kw-hr)
 BINVA(I,19) Defrost Strip Heat (Kw-hr)
 BINVA(I,20) Transient COP

$$=(\text{transient output energy})/(\text{transient input energy})$$

 BINVA(I,21) Normal COP (without Strip)

$$=(\text{normal output energy} - \text{normal } I^2r)/(\text{normal input energy})$$

 BINVA(I,22) Transient + Normal COP (without Strip)

$$=(\text{transient} + \text{normal output energy} - \text{normal } I^2r)/(\text{transient} + \text{normal input energy} + \text{total off-cycle crankcase input})$$

 BINVA(I,23) Normal COP (with Strip)

$$=(\text{normal output energy})/(\text{normal input energy})$$

 BINVA(I,24) Defrost COP (with Strip)

$$=(\text{defrost output energy})/(\text{defrost input energy} + \text{defrost } I^2r)$$

 BINVA(I,25) Overall COP

$$=(\text{total output energy})/(\text{total input energy} + \text{normal } I^2r + \text{defrost } I^2r)$$

 BINVA(I,26) # of Low Speed Cycles
 BINVA(I,27) # of High Speed Cycles
 BINVA(I,28) Low Speed Strip Heat (Kw-hr)

$$=\text{defrost } I^2r + \text{normal } I^2r \text{ for hours that had low speed runtime}$$

 BINVA(I,29) % Time in Defrost

$$=(\text{defrost operating time})/(\text{transient} + \text{normal} + \text{defrost operating time})$$

 BINVA(I,30) % Time in Transient

$$=(\text{transient operating time})/(\text{transient} + \text{normal} + \text{defrost operating time})$$

 BINVA(I,31) Overall COP (without normal strip)

$$=(\text{total output energy} - \text{normal } I^2r)/(\text{total input energy} + \text{defrost } I^2r)$$

The following BINVA's make use of the abbreviations given below:

KWACT=Kw of total input (exclusive of normal I²r)
KWACTT=Kw of total input (inclusive of normal I²r)
COPSS=coefficient of performance based on steady-state data
KWSS=Kw based on COPSS (exclusive of normal I²r)
KWSST=Kw based on COPSS (inclusive of normal I²r)
COPN=coefficient of performance based on normal field data
BO=based on
N=normal field data reference
SS=manufacturer's steady-state data reference
w/o=without

BINVA(I,32) % Degradation Transient (N)

=((KWACT - Kw w/o transient loss (BO COPN))/KWACT) * 100

BINVA(I,33) % Degradation Defrost (N)

=((KWACT - Kw w/o defrost loss (BO COPN))/KWACT) * 100

BINVA(I,34) % Degradation Strip Heat (N)

=((KWACTT - Kw w/o strip heat loss (BO COPN))/KWACTT) * 100

BINVA(I,35) % Degradation Crankcase (N)

=((KWACT - Kw w/o crankcase loss (BO COPN))/KWACT) * 100

BINVA(I,36) % Degradation Transient (SS)

=((KWSS - Kw w/o transient loss (BO COPSS))/KWSS) * 100

BINVA(I,37) % Degradation Defrost (SS)

=((KWSS - Kw w/o defrost loss (BO COPSS))/KWSS) * 100

BINVA(I,38) % Degradation Strip Heat (SS)

=((KWSST - Kw w/o strip heat loss (BO COPSS))/KWSST) * 100

BINVA(I,39) % Degradation Crankcase (SS)

=((KWSS - Kw w/o crankcase loss (BO COPSS))/KWSS) * 100

BINVA(I,40) Temperature Sum (°C)

BINVA(I,41) Relative Humidity Sum (%)

BINVA(I,42) Total Bin Hour Count

BINVA(I,43) Total Runtime Sum (hr)

BINVA(I,44) Crankcase Sum (on + off-time)

BINVA(I,45) Kw w/o Transient Loss (BO COPN)

=KWACT - (transient input - ((transient output)/COPN))

BINVA(I,46) Kw w/o Defrost Loss (BO COPN)

=KWACT - (defrost input + defrost I²r - ((defrost output)/COPN))

BINVA(I,47) Kw w/o Strip Heat Loss (BO COPN)
 =KWACT

 BINVA(I,48) Kw w/o Crankcase Loss (BO COPN)
 =KWACT - off-cycle crankcase input

 BINVA(I,49) Kw w/o Transient Loss (BO COPSS)
 =KWSS - (transient input - ((transient output)/COPSS))

 BINVA(I,50) Kw w/o Defrost Loss (BO COPSS)
 =KWSS - (defrost input + defrost I^2r - ((defrost output)/COPSS))

 BINVA(I,51) Kw w/o Strip Heat Loss (BO COPSS)
 =KWSS

 BINVA(I,52) Kw w/o Crankcase Loss (BO COPSS)
 =KWSS - off-cycle crankcase input

 BINVA(I,53) KWACTT

 BINVA(I,54) KWSST

 BINVA(I,55) Kw BO COPN
 =(total output energy - ((normal I^2r)/COPN) + normal I^2r

 BINVA(I,56) KWACT

 BINVA(I,57) KWSS

 BINVA(I,58) High Speed Runtime (hr)

 BINVA(I,59) Low Speed Runtime (hr)

 BINVA(I,60) Total Runtime (hr)

 BINVA(I,61) High Speed Runtime (High Hours Only)

 BINVA(I,62) Low Speed Runtime (Low Hours Only)

 BINVA(I,63) BINVA(I,61) + BINVA(I,62)

A.11 Single-Speed Mode's Cooling Analysis Computer Program

```

REAL VALUE(40),BINVA(10,46)
REAL IFTOT,OFTOT,LATRO,LANORO,COMTOT,COPN,NORIN,CCTOT
REAL TRSEC,NORSEC,RTHR,KWACT,KWTRIN,TOTOUT,KWSS,COPSS
REAL COPSSL,COPSSH,KWMTLN,KWMCCL,KWATOT,KWMTLS,KWMCCS
REAL KWSSSU
DIMENSION A(30)
INTEGER IDAYS
OPEN(UNIT=45,FILE='SPIDER.DAT')
101 OPEN(UNIT=44,FILE='SPIBIN.DAT')
WRITE(5,327)
327 FORMAT(' WHAT IS THE INPUT FILE')
READ(5,328)FNAM
328 FORMAT(A6)
WRITE(5,329)FNAM
329 FORMAT(' FOR THE WEEK ',A6,' HOW MANY DAYS ARE THERE')
READ(5,330)DAYS
330 FORMAT(F10.0)
IF(DAYS.GE.43)GOTO 843
IDAYS=DAYS
IHOURS=IDAYS*24
800 READ(44,844)TLOW,THIGH,I
844 FORMAT(2F10.4,I2)
IF(TLOW.EQ.843)CLOSE(UNIT=44)
IF(TLOW.EQ.843)GOTO 101
OPEN(UNIT=43,FILE=FNAM)
OPEN(UNIT=47,FILE='NAMSPI.DAT')
DO 750 II=1,IHOURS
READ(43,250)(VALUE(J),J=1,40)
250 FORMAT(8F10.4)
DO 270 K=1,40
IF(VALUE(K).EQ.99999)GOTO 750
270 CONTINUE
IF(VALUE(33).LT.0.0)WRITE(5,78)
78 FORMAT('LOWER THAN 0 C')
IF(VALUE(33).GE.35.0)WRITE(5,79)
79 FORMAT('EQUAL OR GREATER THAN 35 C')
C IF(VALUE(33).GT.35.)WRITE(5,22)(VALUE(J),J=1,40)
22 FORMAT(8F10.4)
IF((VALUE(33) .LT. TLOW) .OR. (VALUE(33) .GE. THIGH))
*GO TO 750
IF(VALUE(23).GT.12.) GO TO 750
BINVA(I,29)=BINVA(I,29)+1
BINVA(I,30)=BINVA(I,30)+VALUE(17)/1000.
C IF(VALUE(2).EQ.0)GO TO 750
C IF(VALUE(22).GT.0)GO TO 750
C IF(VALUE(23).GT.0)GO TO 750
C IF(VALUE(22).EQ.0 .OR. VALUE(23).EQ.0)GO TO 750
NORIN=VALUE(6)+VALUE(9)+VALUE(12)

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      TRSEC=(VALUE(25)+VALUE(26))*240.
      NORSEC=VALUE(22)+VALUE(23)-TRSEC
      IF(TRSEC+NORSEC.LT.26.) GO TO 12
      LATRO=VALUE(39)*0.5*TRSEC/(NORSEC+0.5*TRSEC)
      LANORO=VALUE(39)-LATRO
12      IF(TRSEC+NORSEC.GT.26.) GO TO 17
          LATRO=0.
          LANORO=0.
17      IF(NORIN.LT.10.) GO TO 889
          COPN=(VALUE(29)+LANORO)/NORIN
889      IFTOT=VALUE(5)+VALUE(6)
          OFTOT=VALUE(8)+VALUE(9)
          COMTOT=VALUE(11)+VALUE(12)
          RTHR=(VALUE(22)+VALUE(23))/3600.
          IF(RTHR.LT.1) GO TO 891
              RTHR=1.
891      CCTOT=VALUE(17)*(1.-RTHR)
          KWACT=(IFTOT+OFTOT+COMTOT+CCTOT)/1000.
          KWTRIN=(VALUE(5)+VALUE(8)+VALUE(11))/1000.
          TOTOUT=VALUE(28)+VALUE(29)+VALUE(39)
          BINVA(I,45)=LATRO/1000.+BINVA(I,45)
          BINVA(I,46)=LANORO/1000.+BINVA(I,46)
          IF(VALUE(22).GT.0) GO TO 555
              COPSS=4.586-0.0587*VALUE(33)
              GO TO 557
555      IF(VALUE(23).GT.0) GO TO 556
              COPSS=4.089-0.0466*VALUE(33)
              GO TO 557
556      COPSSH=4.089-0.0466*VALUE(33)
          COPSSL=4.586-0.0587*VALUE(33)
          IF((VALUE(23)+VALUE(22)).LT.26.) GO TO 797
          COPSS=(VALUE(23)*COPSSL+VALUE(22)*COPSSH)
          */(VALUE(22)+VALUE(23))
          IF(COPSS.EQ.0) GO TO 797
557      KWSS=TOTOUT/(1000.*COPSS)
797      IF(COPN.EQ.0) GO TO 558
          BINVA(I,38)=KWACT-(KWTRIN-(VALUE(28)+LATRO)/(1000.*COP
          *N))+BINVA(I,38)
          BINVA(I,44)=TOTOUT/(1000.*COPN)+BINVA(I,44)
558      BINVA(I,43)=KWSS+BINVA(I,43)
          IF(COPSS.EQ.0) GO TO 798
          BINVA(I,40)=KWSS-(KWTRIN-(VALUE(28)+LATRO)/(1000.
          **COPSS))+BINVA(I,40)
798      IF(VALUE(2).LT.16.) GO TO 750
          BINVA(I,3)=BINVA(I,3)+1
          BINVA(I,27)=BINVA(I,27)+VALUE(33)
          BINVA(I,28)=BINVA(I,28)+VALUE(1)
          BINVA(I,4)=(VALUE(25)+VALUE(26))*(4./60.)+BINVA(I,4)
          BINVA(I,5)=BINVA(I,5)+(VALUE(22)+VALUE(23))/3600.
          *-(VALUE(25)+VALUE(26))*(4./60.)
          BINVA(I,6)=BINVA(I,6)+VALUE(25)+VALUE(26)

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BINVA(I,7)=BINVA(I,7)+(VALUE(5)+VALUE(8)+VALUE(11))/1000.
BINVA(I,8)=BINVA(I,8)+(VALUE(6)+VALUE(9)+VALUE(12))/1000.
BINVA(I,31)=BINVA(I,31)+VALUE(28)/1000.
BINVA(I,13)=BINVA(I,13)+VALUE(39)/1000.
BINVA(I,32)=BINVA(I,32)+VALUE(29)/1000.
BINVA(I,15)=BINVA(I,15)+VALUE(20)
BINVA(I,20)=BINVA(I,20)+VALUE(26)
BINVA(I,21)=BINVA(I,21)+VALUE(25)
  BINVA(I,22)=BINVA(I,22)+(VALUE(28)+VALUE(29))/1000.
  BINVA(I,25)=BINVA(I,25)+VALUE(22)/3600.
  BINVA(I,26)=BINVA(I,26)+VALUE(23)/3600.
750  CONTINUE
13   CLOSE(UNIT=43)
      GO TO 800
843  DO 8 I=1,10
      BINVA(I,33)=BINVA(I,4)+BINVA(I,5)
      IF(BINVA(I,29).EQ.0) GO TO 963
      BINVA(I,9)=BINVA(I,30)*((BINVA(I,29)-BINVA(I,33))/
*BINVA(I,29))
963  IF(BINVA(I,33).EQ.0) GO TO 947
947  BINVA(I,11)=BINVA(I,31)+BINVA(I,45)
      BINVA(I,12)=BINVA(I,32)+BINVA(I,46)
      BINVA(I,10)=BINVA(I,7)+BINVA(I,8)+BINVA(I,9)
      BINVA(I,14)=BINVA(I,11)+BINVA(I,12)
      IF(BINVA(I,3).EQ.0)GOTO 88
      BINVA(I,1)=BINVA(I,27)/BINVA(I,3)
      BINVA(I,2)=BINVA(I,28)/BINVA(I,3)
88   IF((BINVA(I,22)+BINVA(I,13)).EQ.0) GO TO 948
      BINVA(I,23)=BINVA(I,22)/(BINVA(I,22)+BINVA(I,13))
948  BINVA(I,40)=BINVA(I,40)+BINVA(I,9)
      BINVA(I,42)=BINVA(I,10)
      BINVA(I,43)=BINVA(I,43)+BINVA(I,9)
      BINVA(I,44)=BINVA(I,44)+BINVA(I,9)
      BINVA(I,39)=BINVA(I,42)-BINVA(I,9)
      BINVA(I,41)=BINVA(I,43)-BINVA(I,9)
      IF(BINVA(I,42).EQ.0) GO TO 964
      BINVA(I,34)=(BINVA(I,42)-BINVA(I,38))/BINVA(I,42)*100.
      BINVA(I,35)=(BINVA(I,42)-BINVA(I,39))/BINVA(I,42)*100.
964  IF(BINVA(I,43).EQ.0) GO TO 965
      BINVA(I,36)=(BINVA(I,43)-BINVA(I,40))/BINVA(I,43)*100.
      BINVA(I,37)=(BINVA(I,43)-BINVA(I,41))/BINVA(I,43)*100.
965  KWMTLN=BINVA(I,38)+KWMTLN
      KWMCCL=BINVA(I,39)+KWMCCL
      KWMTLS=BINVA(I,40)+KWMTLS
      KWMCCS=BINVA(I,41)+KWMCCS
      KWATOT=BINVA(I,42)+KWATOT
      KWSSSU=BINVA(I,43)+KWSSSU
      IF(BINVA(I,4).EQ.0) GO TO 14
      BINVA(I,24)=BINVA(I,4)/(BINVA(I,4)+BINVA(I,5))*100.
      BINVA(I,16)=BINVA(I,11)/BINVA(I,7)
14   IF(BINVA(I,5).EQ.0)GOTO 16

```

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      BINVA(I,17)=BINVA(I,12)/BINVA(I,8)
16      IF((BINVA(I,4)+BINVA(I,5)).EQ.0)GOTO 8
      BINVA(I,18)=BINVA(I,14)/(BINVA(I,7)+BINVA(I,8))
      BINVA(I,19)=BINVA(I,14)/(BINVA(I,7)+BINVA(I,8)+BINVA(I,9))
8      CONTINUE
      WRITE(5,70)
70      FORMAT(' DIVIDE CHECK NUMBER 1')
801     WRITE(45,846)
846     FORMAT(1H ,/)
      WRITE(45,5678)
5678    FORMAT(36X,' 0/5      ','5/10      ','10/15      ','15/20      ',
* '20/25      ','25/30      ','30/35      ',' 35/40',' 40/45',
* ' 45/50')
      DO 3 L=1,46
      READ(47,847)(A(J),J=1,34)
847     FORMAT(34A1)
      WRITE(45,845)(A(J),J=1,34),(BINVA(M,L),M=1,10)
845     FORMAT(1X,34(A1),10(F8.3))
3      CONTINUE
      WRITE(5,71) KWATOT,KWSSSU
71     FORMAT(' KWATOT=',F10.3,4X,'KWSSSU=',F10.3)
      WRITE(5,72) KWMTLN,KWMCCL,KWMTLS,KWMCCS
72     FORMAT(' KWMTLN=',F10.3,2X,' KWMCCL=',F10.3,2X,' KWMTLS=
*,F10.3,2X,' KWMCCS=',F10.3)
      DTRN=(KWATOT-KWMTLN)/KWATOT*100.
      DCCN=(KWATOT-KWMCCL)/KWATOT*100.
      DTRSS=(KWSSSU-KWMTLS)/KWSSSU*100.
      DCCSS=(KWSSSU-KWMCCS)/KWSSSU*100.
29     WRITE(45,1050)
1050    FORMAT(1X)
      WRITE(45,1055)
1055    FORMAT(' NORMAL DEGRADATION FACTORS:')
      WRITE(45,1060) DTRN,DCCN
1060    FORMAT(2X,'TRANSIENT=',F4.1,4X,'CRANKCASE=',F4.1)
      WRITE(45,1080)
1080    FORMAT(1X)
      WRITE(45,1090)
1090    FORMAT(' STEADY STATE DEGRADATION FACTORS:')
      WRITE(45,1100) DTRSS,DCCSS
1100    FORMAT(2X,'TRANSIENT=',F4.1,4X,'CRANKCASE=',F4.1)
850     CLOSE(UNIT=45)
      CLOSE(UNIT=47)
      STOP
      END

```

A.12 Dual-Speed Mode's Cooling Analysis Computer Program

```

REAL VALUE(40),BINVA(10,46)
REAL IFTOT,OFTOT,LATRO,LANORO,COMTOT,COPN,NORIN,CCTOT
REAL TRSEC,NORSEC,RTHR,KWACT,KWTRIN,TOTOUT,KWSS,COPSS
REAL COPSSL,COPSSH,KWMTLN,KWMCCL,KWATOT,KWMTLS,KWMCCS
REAL KWSSSU
DIMENSION A(30)
INTEGER IDAYS
OPEN(UNIT=45,FILE='SPIDER.DAT')
101 OPEN(UNIT=44,FILE='SPIBIN.DAT')
WRITE(5,327)
327 FORMAT(' WHAT IS THE INPUT FILE')
READ(5,328)FNAM
328 FORMAT(A6)
WRITE(5,329)FNAM
329 FORMAT(' FOR THE WEEK ',A6,' HOW MANY DAYS ARE THERE')
READ(5,330)DAYS
330 FORMAT(F10.0)
IF(DAYS.GE.43)GOTO 843
IDAYS=DAYS
IHOURLS=IDAYS*24
800 READ(44,844)TLOW,THIGH,I
844 FORMAT(2F10.4,I2)
IF(TLOW.EQ.843)CLOSE(UNIT=44)
IF(TLOW.EQ.843)GOTO 101
OPEN(UNIT=43,FILE=FNAM)
OPEN(UNIT=47,FILE='NAMSPI.DAT')
DO 750 II=1,IHOURLS
READ(43,250)(VALUE(J),J=1,40)
250 FORMAT(8F10.4)
DO 270 K=1,40
IF(VALUE(K).EQ.99999)GOTO 750
270 CONTINUE
IF(VALUE(33).LT.0.0)WRITE(5,78)
78 FORMAT('LOWER THAN 0 C')
IF(VALUE(33).GE.35.0)WRITE(5,79)
79 FORMAT('EQUAL OR GREATER THAN 35 C')
C IF(VALUE(33).GT.35.)WRITE(5,22)(VALUE(J),J=1,40)
22 FORMAT(8F10.4)
IF((VALUE(33).LT. TLOW) .OR. (VALUE(33) .GE. THIGH))
*GO TO 750
C IF(VALUE(23).GT.12.) GO TO 750
BINVA(I,29)=BINVA(I,29)+1
BINVA(I,30)=BINVA(I,30)+VALUE(17)/1000.
C IF(VALUE(2).EQ.0)GO TO 750
C IF(VALUE(22).GT.0)GO TO 750
C IF(VALUE(23).GT.0)GO TO 750
C IF(VALUE(22).EQ.0 .OR. VALUE(23).EQ.0)GO TO 750
NORIN=VALUE(6)+VALUE(9)+VALUE(12)

```

```

      TRSEC=(VALUE(25)+VALUE(26))*240.
      NORSEC=VALUE(22)+VALUE(23)-TRSEC
      IF(TRSEC+NORSEC.LT.26.) GO TO 12
      LATRO=VALUE(39)*0.5*TRSEC/(NORSEC+0.5*TRSEC)
      LANORO=VALUE(39)-LATRO
12      IF(TRSEC+NORSEC.GT.26.) GO TO 17
          LATRO=0.
          LANORO=0.
17      IF(NORIN.LT.10.) GO TO 889
          COPN=(VALUE(29)+LANORO)/NORIN
889      IFTOT=VALUE(5)+VALUE(6)
          OFTOT=VALUE(8)+VALUE(9)
          COMTOT=VALUE(11)+VALUE(12)
          RTHR=(VALUE(22)+VALUE(23))/3600.
          IF(RTHR.LT.1) GO TO 891
              RTHR=1.
891      CCTOT=VALUE(17)*(1.-RTHR)
          KWACT=(IFTOT+OFTOT+COMTOT+CCTOT)/1000.
          KWTRIN=(VALUE(5)+VALUE(8)+VALUE(11))/1000.
          TOTOUT=VALUE(28)+VALUE(29)+VALUE(39)
          BINVA(I,45)=LATRO/1000.+BINVA(I,45)
          BINVA(I,46)=LANORO/1000.+BINVA(I,46)
          IF(VALUE(22).GT.0) GO TO 555
              COPSS=4.586-0.0587*VALUE(33)
              GO TO 557
555      IF(VALUE(23).GT.0) GO TO 556
              COPSS=4.089-0.0466*VALUE(33)
              GO TO 557
556      COPSSH=4.089-0.0466*VALUE(33)
          COPSSL=4.586-0.0587*VALUE(33)
          IF((VALUE(23)+VALUE(22)).LT.26.) GO TO 797
          COPSS=(VALUE(23)*COPSSL+VALUE(22)*COPSSH)
          */(VALUE(22)+VALUE(23))
          IF(COPSS.EQ.0) GO TO 797
557      KWSS=TOTOUT/(1000.*COPSS)
797      IF(COPN.EQ.0) GO TO 558
          BINVA(I,38)=KWACT-(KWTRIN-(VALUE(28)+LATRO)/(1000.*COP
          *N))+BINVA(I,38)
          BINVA(I,44)=TOTOUT/(1000.*COPN)+BINVA(I,44)
558      BINVA(I,43)=KWSS+BINVA(I,43)
          IF(COPSS.EQ.0) GO TO 798
          BINVA(I,40)=KWSS-(KWTRIN-(VALUE(28)+LATRO)/(1000.
          **COPSS))+BINVA(I,40)
798      IF(VALUE(2).LT.16.) GO TO 750
          BINVA(I,3)=BINVA(I,3)+1
          BINVA(I,27)=BINVA(I,27)+VALUE(33)
          BINVA(I,28)=BINVA(I,28)+VALUE(1)
          BINVA(I,4)=(VALUE(25)+VALUE(26))*(4./60.)+BINVA(I,4)
          BINVA(I,5)=BINVA(I,5)+(VALUE(22)+VALUE(23))/3600.
          *-(VALUE(25)+VALUE(26))*(4./60.)
          BINVA(I,6)=BINVA(I,6)+VALUE(25)+VALUE(26)

```

```

BINVA(I,7)=BINVA(I,7)+(VALUE(5)+VALUE(8)+VALUE(11))/1000.
BINVA(I,8)=BINVA(I,8)+(VALUE(6)+VALUE(9)+VALUE(12))/1000.
BINVA(I,31)=BINVA(I,31)+VALUE(28)/1000.
BINVA(I,13)=BINVA(I,13)+VALUE(39)/1000.
BINVA(I,32)=BINVA(I,32)+VALUE(29)/1000.
BINVA(I,15)=BINVA(I,15)+VALUE(20)
BINVA(I,20)=BINVA(I,20)+VALUE(26)
BINVA(I,21)=BINVA(I,21)+VALUE(25)
BINVA(I,22)=BINVA(I,22)+(VALUE(28)+VALUE(29))/1000.
BINVA(I,25)=BINVA(I,25)+VALUE(22)/3600.
BINVA(I,26)=BINVA(I,26)+VALUE(23)/3600.
750  CONTINUE
13   CLOSE(UNIT=43)
      GO TO 800
843  DO 8 I=1,10
      BINVA(I,33)=BINVA(I,4)+BINVA(I,5)
      IF(BINVA(I,29).EQ.0) GO TO 963
      BINVA(I,9)=BINVA(I,30)*((BINVA(I,29)-BINVA(I,33)))/
      *BINVA(I,29))
963  IF(BINVA(I,33).EQ.0) GO TO 947
947  BINVA(I,11)=BINVA(I,31)+BINVA(I,45)
      BINVA(I,12)=BINVA(I,32)+BINVA(I,46)
      BINVA(I,10)=BINVA(I,7)+BINVA(I,8)+BINVA(I,9)
      BINVA(I,14)=BINVA(I,11)+BINVA(I,12)
      IF(BINVA(I,3).EQ.0)GOTO 88
      BINVA(I,1)=BINVA(I,27)/BINVA(I,3)
      BINVA(I,2)=BINVA(I,28)/BINVA(I,3)
88   IF((BINVA(I,22)+BINVA(I,13)).EQ.0) GO TO 948
      BINVA(I,23)=BINVA(I,22)/(BINVA(I,22)+BINVA(I,13))
948  BINVA(I,40)=BINVA(I,40)+BINVA(I,9)
      BINVA(I,42)=BINVA(I,10)
      BINVA(I,43)=BINVA(I,43)+BINVA(I,9)
      BINVA(I,44)=BINVA(I,44)+BINVA(I,9)
      BINVA(I,39)=BINVA(I,42)-BINVA(I,9)
      BINVA(I,41)=BINVA(I,43)-BINVA(I,9)
      IF(BINVA(I,42).EQ.0) GO TO 964
      BINVA(I,34)=(BINVA(I,42)-BINVA(I,38))/BINVA(I,42)*100.
      BINVA(I,35)=(BINVA(I,42)-BINVA(I,39))/BINVA(I,42)*100.
964  IF(BINVA(I,43).EQ.0) GO TO 965
      BINVA(I,36)=(BINVA(I,43)-BINVA(I,40))/BINVA(I,43)*100.
      BINVA(I,37)=(BINVA(I,43)-BINVA(I,41))/BINVA(I,43)*100.
965  KWMTLN=BINVA(I,38)+KWMTLN
      KWMCCCL=BINVA(I,39)+KWMCCCL
      KWMTLS=BINVA(I,40)+KWMTLS
      KWMCCS=BINVA(I,41)+KWMCCS
      KWATOT=BINVA(I,42)+KWATOT
      KWSSSU=BINVA(I,43)+KWSSSU
      IF(BINVA(I,4).EQ.0) GO TO 14
      BINVA(I,24)=BINVA(I,4)/(BINVA(I,4)+BINVA(I,5))*100.
      BINVA(I,16)=BINVA(I,11)/BINVA(I,7)
14   IF(BINVA(I,5).EQ.0)GOTO 16

```

```

      BINVA(I,17)=BINVA(I,12)/BINVA(I,8)
16      IF((BINVA(I,4)+BINVA(I,5)).EQ.0)GOTO 8
      BINVA(I,18)=BINVA(I,14)/(BINVA(I,7)+BINVA(I,8))
      BINVA(I,19)=BINVA(I,14)/(BINVA(I,7)+BINVA(I,8)+BINVA(I,9))
      8      CONTINUE
      WRITE(5,70)
70      FORMAT(' DIVIDE CHECK NUMBER 1')
      801      WRITE(45,846)
846      FORMAT(1H ,/)
      WRITE(45,5678)
5678     FORMAT(36X,' 0/5      ','5/10      ','10/15      ','15/20      ',
* '20/25      ','25/30      ','30/35      ',' 35/40',' 40/45',
* ' 45/50')
      DO 3 L=1,46
      READ(47,847)(A(J),J=1,34)
      847      FORMAT(34A1)
      WRITE(45,845)(A(J),J=1,34),(BINVA(M,L),M=1,10)
845      FORMAT(1X,34(A1),10(F8.3))
      3      CONTINUE
      WRITE(5,71) KWATOT,KWSSSU
71      FORMAT(' KWATOT=',F10.3,4X,'KWSSSU=',F10.3)
      WRITE(5,72) KWMTLN,KWMCCL,KWMTLS,KWMCCS
72      FORMAT(' KWMTLN=',F10.3,2X,' KWMCCL=',F10.3,2X,' KWMTLS=
*,F10.3,2X,' KWMCCS=',F10.3)
      DTRN=(KWATOT-KWMTLN)/KWATOT*100.
      DCCN=(KWATOT-KWMCCL)/KWATOT*100.
      DTRSS=(KWSSSU-KWMTLS)/KWSSSU*100.
      DCCSS=(KWSSSU-KWMCCS)/KWSSSU*100.
29      WRITE(45,1050)
1050     FORMAT(1X)
      WRITE(45,1055)
1055     FORMAT(' NORMAL DEGRADATION FACTORS:')
      WRITE(45,1060) DTRN,DCCN
1060     FORMAT(2X,'TRANSIENT=',F4.1,4X,'CRANKCASE=',F4.1)
      WRITE(45,1080)
1080     FORMAT(1X)
      WRITE(45,1090)
1090     FORMAT(' STEADY STATE DEGRADATION FACTORS:')
      WRITE(45,1100) DTRSS,DCCSS
1100     FORMAT(2X,'TRANSIENT=',F4.1,4X,'CRANKCASE=',F4.1)
850      CLOSE(UNIT=45)
      CLOSE(UNIT=47)
      STOP
      END

```

A.13 Cooling Bin Value Descriptions

BINVA(I,1) Average Dry Bulb Temperature (°C)
= (Σ outside dry bulb temperature) / # of hours in bin

BINVA(I,2) Average Bin Relative Humidity (%)
= (Σ outdoor relative humidity) / # of hours in bin

BINVA(I,3) # of Operating Hours in Bin

BINVA(I,4) Transient Operating Time (hr)

BINVA(I,5) Normal Operating Time (hr)

BINVA(I,6) # of Start-up Cycles

BINVA(I,7) Transient Input Energy (Kw-hr)
= indoor fan transient + outdoor fan transient + compressor transient

BINVA(I,8) Normal Input Energy (Kw-hr)
= indoor fan normal + outdoor fan normal + compressor normal

BINVA(I,9) Total Off-Cycle Crankcase Input (Kw-hr)
= crankcase input (on + off-cycle) * ((total bin hour count - total runtime) / (total bin hour count))

BINVA(I,10) Total Input Energy (Kw-hr)
= transient + normal + off-cycle inputs

BINVA(I,11) Transient Output Energy (Kw-hr)
= transient sensible heat flow to airstream + transient latent output

BINVA(I,12) Normal Output Energy (Kw-hr)
= normal sensible heat flow to airstream + normal latent output

BINVA(I,13) Latent Cooling Load (Kw-hr)

BINVA(I,14) Total Output Energy (Kw-hr)
= transient + normal output energy

BINVA(I,15) Condensate Collected (Kg)

BINVA(I,16) Transient COP (without Crankcase)
= (transient output energy) / (transient input energy)

BINVA(I,17) Normal COP (without Crankcase)
= (normal output energy) / (normal input energy)

BINVA(I,18) Overall COP (without Crankcase)

$$=(\text{total output energy})/(\text{transient} + \text{normal input energy})$$

BINVA(I,19) Overall COP (with Crankcase)

$$=(\text{total output energy})/(\text{total input energy})$$

BINVA(I,20) # of Low Speed Cycles

BINVA(I,21) # of High Speed Cycles

BINVA(I,22) Sensible Output Energy (Kw-hr)

$$=\text{transient} + \text{normal sensible heat flows to airstream}$$

BINVA(I,23) Sensible Heat Ratio

$$=(\text{sensible output energy})/(\text{latent} + \text{sensible output energy})$$

BINVA(I,24) % Time in Transient

$$=(\text{transient operating time})/(\text{transient} + \text{normal operating time})$$

BINVA(I,25) High Speed Runtime (hr)

BINVA(I,26) Low Speed Runtime (hr)

BINVA(I,27) Temperature Sum (°C)

BINVA(I,28) Relative Humidity Sum (%)

BINVA(I,29) Total Bin Hour Count

BINVA(I,30) Crankcase Sum (Kw-hr)

BINVA(I,31) Transient Sensible Heat Flow (Kw-hr)

BINVA(I,32) Normal Sensible Heat Flow (Kw-hr)

BINVA(I,33) Total Operating Time (hr)

The following BINVA's make use of the abbreviations given below:

KWACT=Kw of total input

COPSS=coefficient of performance based on steady-state data

KWSS=Kw based on COPSS

COPN=coefficient of performance based on normal field data

BO=based on

N=normal field data reference

SS=manufacturer's steady-state data reference

w/o=without

BINVA(I,34) % Degradation Transient (N)

$$=((\text{KWACT} - \text{Kw w/o transient loss (BO COPN)})/\text{KWACT}) * 100$$

BINVA(I,35) % Degradation Crankcase (N)

```

      =((KWACT - Kw w/o crankcase loss (BO COPN))/KWACT) * 100

BINVA(I,36) % Degradation Transient (SS)
      =((KWSS - Kw w/o transient loss (BO COPSS))/KWSS) * 100

BINVA(I,37) % Degradation Crankcase (SS)
      =((KWSS - Kw w/o crankcase loss (BO COPSS))/KWSS) * 100

BINVA(I,38) Kw w/o Transient Loss (BO COPN)
      =KWACT - (transient input - (transient output)/COPN)

BINVA(I,39) Kw w/o Crankcase Loss (BO COPN)
      =KWACT - off-cycle crankcase input

BINVA(I,40) Kw w/o Transient Loss (BO COPSS)
      =KWSS - (transient input - (transient output)/COPSS)

BINVA(I,41) Kw w/o Crankcase Loss (BO COPSS)
      =KWSS - off-cycle crankcase input

BINVA(I,42) KWACT

BINVA(I,43) KWSS

BINVA(I,44) Kw BO COPN

BINVA(I,45) Transient Latent Output (Kw-hr)
      =latent load * 0.5 * transient operating time/(normal operating
        time + 0.5 * transient operating time)

BINVA(I,46) Normal Latent Output (Kw-hr)
      =total latent output - transient latent output

```

APPENDIX B

B.1 Single-Speed Mode HVAC System Data File

SAMPLE RUN OF A LENNOX 2-SPEED WITH HIGH SPEED COMPRESSOR OPERATION ONLY
 LENNOX(2-SPEED) HP14 LEGEND II SERIES--HP14-261/411V W CP12-41V/E12Q3

01 01 01 02 05 01

01 10

-15.00	5.00	15.00	25.00	35.00	45.00	50.00	55.00	60.00	65.00
--------	------	-------	-------	-------	-------	-------	-------	-------	-------

1.00

1.49	1.94	2.10	2.33	2.58	2.84	2.98	3.13	3.26	3.40
------	------	------	------	------	------	------	------	------	------

7.60	14.80	19.30	23.77	29.29	34.00	36.70	39.46	42.09	44.60
------	-------	-------	-------	-------	-------	-------	-------	-------	-------

0.20	835.00	0.00	835.00
------	--------	------	--------

-1.00	-0.9346	42.00	-1.00	-1.00
-------	---------	-------	-------	-------

10.00	-1.00	-1.00
-------	-------	-------

01 04

75.00	85.00	95.00	105.00
-------	-------	-------	--------

1.00

3.17	3.34	3.50	3.66
------	------	------	------

28.53	27.52	26.50	25.49
-------	-------	-------	-------

0.13	835.00	0.00	835.00
------	--------	------	--------

0.00

B.2 Dual-Speed Mode HVAC System Data File

SAMPLE RUN OF A LENNOX TWO-SPEED WITH LOW-SPEED LOCKOUT IN HEATING

LENNOX(2-SPEED) HP14 LEGEND II SERIES--HP14-261/411V W CP12-41V/E12Q3

01 03 01 02 05 01

02 10

-15.00	5.00	15.00	25.00	35.00	45.00	50.00	55.00	60.00	65.00
0.50									
0.01	0.01	0.01	1.14	1.22	1.31	1.35	1.40	1.44	1.48
0.00	0.00	0.00	14.12	17.76	21.40	23.20	25.10	26.80	28.70
0.22	835.00	0.00	835.00						
-1.00	-0.9346	37.00	-1.00	-1.00					
1.00									
1.49	1.94	2.10	2.33	2.58	2.84	2.98	3.13	3.26	3.40
7.60	14.80	19.30	23.77	29.29	34.00	36.70	39.46	42.09	44.60
0.20	835.00	0.00	835.00						
-1.00	-0.9346	42.00	-1.00	-1.00					
10.00	-1.00	-1.00							

02 04

75.00	85.00	95.00	105.00
0.50			
1.36	1.44	1.56	1.68
18.32	18.01	17.70	17.40
0.13	835.00	0.00	835.00
1.00			
3.17	3.34	3.50	3.66
28.53	27.52	26.50	25.49
0.13	835.00	0.00	835.00
0.00			

B.3 Single-Speed Mode Load Data File

167 M**2 RANCH, TECH HOUSE 3

KNOXVILLE, TN

	1800.00	38.000	19.00									
	70.00	78.00	67.00	13.00	92.00	30.00	22.00					
	1	2	3	4	5	6	7	8	9	10	11	12
17												
2.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7.0	24.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	6.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	6.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12.0	26.82	24.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	24.09
	20.00	7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.00
	10.70	10.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.80
17.0	32.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	22.71
	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
17.0	23.99	22.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	21.90
	37.00	10.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.00
	14.40	14.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.20
22.0	23.36	25.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	23.03
	9.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
22.0	20.80	20.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	19.92
	22.00	13.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.00
	18.80	18.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	19.15
27.0	19.54	22.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	17.53
	19.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.00
27.0	17.71	16.63	15.52	15.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.46
	47.00	30.00	5.00	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	25.00
	23.10	23.00	22.70	25.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	23.80
32.0	14.58	15.93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.15
	32.00	9.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.00
32.0	15.27	11.98	13.10	13.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.26
	45.00	18.00	23.00	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	20.00
	27.00	26.80	28.00	26.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	28.10
37.0	16.48	14.16	14.32	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.71
	29.00	26.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.00
37.0	14.06	12.59	9.70	16.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.11
	38.00	39.00	15.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	31.00
	31.20	33.40	31.25	31.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	33.00

42.0	10.91	10.44	15.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.66
	18.00	9.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.00
42.0	12.76	4.61	4.81	5.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.85
	9.00	17.00	17.00	9.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.00
	34.10	35.00	34.75	36.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	37.00
47.0	6.96	9.02	8.88	12.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.04
	2.00	3.00	4.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.00
47.0	0.00	0.50	2.47	1.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.43
	0.00	7.00	24.00	12.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.00
	36.75	39.00	38.20	41.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	39.50
52.0	0.00	5.76	4.20	9.81	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.68
	0.00	6.00	11.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.00
52.0	0.00	0.00	0.54	0.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.22
	0.00	7.00	17.00	15.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.00
	0.00	42.00	42.75	46.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	46.00
57.0	0.00	3.30	2.66	4.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	4.00	12.00	7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
57.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	7.00	23.00	17.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	47.00	47.70	48.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
62.0	0.00	1.07	2.02	1.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	8.00	21.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
62.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	17.00	30.00	8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	50.90	51.00	52.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
67.0	0.00	0.48	0.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	9.00	22.00	12.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
67.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	3.00	31.00	8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	53.70	57.00	54.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
72.0	0.00	0.00	0.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	7.00	14.00	12.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
72.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	5.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	55.50	60.50	56.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
77.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	5.00	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
77.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	64.00	60.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
82.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
82.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	66.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10												
52.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

52.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	3.00	0.00	0.00	10.00	0.00	0.00	0.00
57.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00
57.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	17.00	0.00	0.00	10.00	0.00	0.00	0.00
62.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.00	0.00	0.00	0.00
62.0	0.00	0.00	0.00	0.00	0.00	2.61	1.21	1.14	1.28	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.68	0.32	0.32	0.29	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	13.00	15.00	16.00	28.00	0.00	0.00	0.00
67.0	0.00	0.00	0.00	0.00	0.00	4.75	0.00	3.83	0.17	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	1.24	0.00	0.96	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	2.00	1.00	5.00	5.00	0.00	0.00	0.00
67.0	0.00	0.00	0.00	0.00	0.00	3.36	3.07	3.86	4.45	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.85	0.79	1.04	1.08	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	43.00	64.00	86.00	29.00	0.00	0.00	0.00
72.0	0.00	0.00	0.00	0.00	0.00	3.34	5.63	3.81	2.92	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	1.04	1.48	1.03	0.60	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	8.00	7.00	21.00	22.00	0.00	0.00	0.00
72.0	0.00	0.00	0.00	0.00	0.00	7.64	6.22	5.91	7.14	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	2.05	1.66	1.57	1.81	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	24.00	72.00	87.00	24.00	0.00	0.00	0.00
77.0	0.00	0.00	0.00	0.00	0.00	6.30	5.64	10.19	4.25	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	1.80	1.60	2.63	1.07	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	17.00	21.00	25.00	5.00	0.00	0.00	0.00
77.0	0.00	0.00	0.00	0.00	0.00	10.84	9.11	11.28	13.34	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	2.81	2.43	2.93	3.46	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	8.00	37.00	28.00	8.00	0.00	0.00	0.00
82.0	0.00	0.00	0.00	0.00	0.00	7.40	8.91	10.20	10.86	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	1.77	2.34	2.69	2.67	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	16.00	26.00	44.00	12.00	0.00	0.00	0.00
82.0	0.00	0.00	0.00	0.00	0.00	9.82	14.89	16.96	17.36	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	2.67	3.77	4.21	4.44	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	3.00	17.00	25.00	6.00	0.00	0.00	0.00
87.0	0.00	0.00	0.00	0.00	0.00	10.01	10.17	13.04	12.60	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	2.49	2.56	3.23	3.26	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	12.00	37.00	21.00	12.00	0.00	0.00	0.00
87.0	0.00	0.00	0.00	0.00	0.00	19.34	17.21	19.48	19.96	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	4.32	4.01	4.76	4.80	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	1.00	10.00	4.00	1.00	0.00	0.00	0.00
92.0	0.00	0.00	0.00	0.00	0.00	13.37	12.69	15.68	12.36	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	3.02	2.89	3.89	3.16	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	1.00	16.00	8.00	3.00	0.00	0.00	0.00
92.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

97.0	0.00	0.00	0.00	0.00	0.00	0.00	15.62	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	3.28	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00
97.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

B.4 Dual-Speed Mode Load Data File

167**2 RANCH, TECH HOUSE 3

KNOXVILLE, TN

	1800.00	38.00	19.00									
	70.00	78.00	67.00	13.00	92.00	30.00	22.00					
	1	2	3	4	5	6	7	8	9	10	11	12
20												
-13.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-13.0	36.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-14.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-8.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-8.0	39.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-9.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-3.0	24.93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-3.0	31.74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-4.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.0	25.89	0.00	11.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	7.00	0.00	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.0	31.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
-0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7.0	22.95	29.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	7.10	7.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12.0	22.10	22.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	1.00	6.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	11.10	9.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17.0	22.65	22.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	11.00	8.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	15.00	14.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22.0	0.00	23.96	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22.0	19.62	22.56	19.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	6.00	18.00	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	18.25	18.40	20.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
27.0	23.61	22.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2.00	7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

27.0	19.01	16.55	15.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	9.00	33.00	10.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	23.25	23.70	24.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
32.0	15.45	16.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	9.00	13.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
32.0	17.97	15.18	13.05	14.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	34.00	33.00	42.00	12.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	27.25	28.00	27.00	29.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
37.0	15.56	13.82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.90
	22.00	20.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00
37.0	15.29	9.58	8.51	9.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.39
	23.00	16.00	30.00	14.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.00
	33.00	31.50	30.70	32.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	31.60
42.0	12.61	10.32	13.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.93
	12.00	8.00	6.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.00
42.0	11.24	6.55	5.92	6.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.19
	11.00	11.00	29.00	26.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	36.00
	37.00	34.00	36.00	37.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	39.30
47.0	0.00	4.76	6.42	7.53	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.60
	0.00	6.00	19.00	6.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.00
47.0	0.00	1.70	4.18	3.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.26
	0.00	11.00	66.00	19.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	32.00
	0.00	37.60	40.35	41.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	43.00
52.0	0.00	5.93	4.73	6.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.99
	0.00	5.00	34.00	9.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8.00
52.0	0.00	1.70	2.43	1.94	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.06
	0.00	19.00	39.00	12.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	37.00
	0.00	42.00	43.50	43.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	47.00
57.0	0.00	1.71	2.55	5.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.31
	0.00	11.00	34.00	13.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	17.00
57.0	0.00	0.00	0.56	0.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	2.00	22.00	7.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	35.00
	0.00	40.50	44.50	47.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	50.50
62.0	0.00	1.68	1.93	4.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.24
	0.00	3.00	19.00	6.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.00
62.0	0.00	0.00	0.00	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	2.00	7.00	10.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.00
	0.00	47.50	46.50	50.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	54.00
67.0	0.00	0.00	1.30	2.97	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11
	0.00	3.00	11.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	26.00
67.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	6.00	6.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.00
	0.00	50.00	49.00	53.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	56.50
72.0	0.00	0.00	0.00	0.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	2.00	12.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.00
72.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	52.50	55.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	58.80
77.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	4.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

77.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	56.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
82.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
82.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	59.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11												
52.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
52.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	13.00	0.00	0.00	19.00	0.00	0.00	0.00
57.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
57.0	0.00	0.00	0.00	0.00	0.00	0.60	0.00	1.46	0.53	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	9.00	0.00	2.00	23.00	0.00	0.00	0.00
62.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00
62.0	0.00	0.00	0.00	0.00	0.00	1.69	0.00	1.95	2.31	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.26	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	24.00	0.00	14.00	22.00	0.00	0.00	0.00
67.0	0.00	0.00	0.00	0.00	0.00	1.12	0.00	2.80	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.22	0.00	0.33	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	10.00	0.00	7.00	5.00	0.00	0.00	0.00
67.0	0.00	0.00	0.00	0.00	0.00	3.88	4.35	3.12	4.35	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.57	0.76	0.54	0.50	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	49.00	28.00	82.00	41.00	0.00	0.00	0.00
72.0	0.00	0.00	0.00	0.00	0.00	2.87	5.18	3.69	1.79	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.57	0.92	0.59	0.28	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	12.00	1.00	24.00	4.00	0.00	0.00	0.00
72.0	0.00	0.00	0.00	0.00	0.00	6.01	5.94	6.49	7.49	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.75	1.04	1.29	1.22	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	41.00	49.00	53.00	39.00	0.00	0.00	0.00
77.0	0.00	0.00	0.00	0.00	0.00	3.09	5.76	7.29	4.05	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.26	0.93	1.42	0.33	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	14.00	6.00	29.00	18.00	0.00	0.00	0.00
77.0	0.00	0.00	0.00	0.00	0.00	10.99	10.49	12.22	11.56	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	1.56	2.01	2.50	1.40	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	18.00	22.00	14.00	22.00	0.00	0.00	0.00
82.0	0.00	0.00	0.00	0.00	0.00	9.07	10.33	7.51	5.72	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	1.07	1.54	1.18	0.32	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	32.00	13.00	5.00	34.00	0.00	0.00	0.00
82.0	0.00	0.00	0.00	0.00	0.00	13.08	14.25	13.53	16.92	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	1.48	2.51	2.82	2.91	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	9.00	15.00	5.00	5.00	0.00	0.00	0.00

87.0	0.00	0.00	0.00	0.00	0.00	9.81	11.77	10.39	11.60	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	1.26	1.85	1.99	1.97	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	17.00	24.00	14.00	21.00	0.00	0.00	0.00
87.0	0.00	0.00	0.00	0.00	0.00	17.07	18.59	12.49	18.25	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	2.62	3.16	2.47	3.63	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	3.00	5.00	6.00	2.00	0.00	0.00	0.00
92.0	0.00	0.00	0.00	0.00	0.00	9.98	13.02	11.85	13.48	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	1.31	2.11	2.19	2.43	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	2.00	19.00	7.00	6.00	0.00	0.00	0.00
92.0	0.00	0.00	0.00	0.00	0.00	0.00	18.62	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	3.31	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
97.0	0.00	0.00	0.00	0.00	0.00	0.00	14.61	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	2.54	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00
97.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
102.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15.03	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00
102.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

B.5 Heating Season Load Manipulation Computer Program

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C
C   THE FOLLOWING PROGRAM SUMS UP THE DAY AND NIGHT HEATING
C   LOADS ALONG WITH THE NUMBER OF OPERATING HOURS FOR BOTH
C   DAY AND NIGHT. OUTPUT IS IN FARENHEIT TEMPERATURE BINS.
C   ALSO, IT COUNTS THE NUMBER OF GOOD DATA HOURS FOR EACH
C   SET OF DATA.
C
REAL VALUE(40),DLOAD(21),NLOAD(21),TLOAD
REAL DHOURS(21),NHOURS(21),TEMPF,LSSH
REAL SUMDB(21),AVGDB(21),SUMRH(21),AVGRH(21)
REAL SUMHR(21),RTHR
OPEN(UNIT=45,FILE='JC1.DAT')
101 OPEN(UNIT=44,FILE='NUT1.DAT')
WRITE(5,100)
100 FORMAT(' WHAT IS THE INPUT FILE')
READ (5,110) FNAME
110 FORMAT(A5)
WRITE(5,120) FNAME
120 FORMAT(' FOR THE WEEK',A6,' HOW MANY HOURS WILL BE AVAILABLE')
READ(5,130) IHOURS
130 FORMAT(I3)
DO 135 I=1,21
    DLOAD(I)=0.
    DHOURS(I)=0.
    NLOAD(I)=0.
    NHOURS(I)=0.
    SUMDB(I)=0.
    AVGDB(I)=0.
    SUMRH(I)=0.
    AVGRH(I)=0.
    SUMHR(I)=0.
135 CONTINUE
IHRSGD=0
800 READ(44,200) TLOW,THIGH,I
200 FORMAT(2X,F8.2,2X,F8.2,2X,I2)
IF(TLOW.EQ.843.00) CLOSE(UNIT=44)
IF(TLOW.EQ.843.00) GO TO 801
OPEN(UNIT=43,FILE=FNAME)
IN=0
DO 750 II=1,IHOURS
    IN=IN+1
    READ(43,300) (VALUE(J),J=1,40)
300 FORMAT(8F10.4)
DO 320 K=1,40
    IF(VALUE(K).EQ.99999) GO TO 749
320 CONTINUE
TEMPF=1.80*VALUE(33)+32.0
IF(TEMPF .LT. -15.5) WRITE(5,340)
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340  FORMAT(' LOWER THAN -15.5 F')
      IF(TEMPF .GT. 89.5) WRITE(5,360)
360  FORMAT(' GREATER THAN 89.5 F')
      IF((TEMPF .LT. TLOW) .OR. (TEMPF .GE. THIGH)) GO TO 749
      LSSH=0.
      IF(VALUE(23).LT.27.) GO TO 365
          LSSH=VALUE(15)
365  IF(LSSH.GT.100.) WRITE(5,375) FNAME,II
375  FORMAT(' HEY BUCKO, FNAME=',A5,' FOR II=',I3)
      IF(LSSH.GT.100.) GO TO 749
      SUMDB(I)=TEMPF+SUMDB(I)
      SUMRH(I)=VALUE(1)+SUMRH(I)
      SUMHR(I)=SUMHR(I)+1
      IHRSGD=IHRSGD+1
      IF((IN .GT. 9) .AND. (IN .LT. 18)) GO TO 400
      NHOURS(I)=NHOURS(I)+1.
      GO TO 449
400  DHOURLS(I)=DHOURLS(I)+1.
449  IF(VALUE(2).LT.16.0) GO TO 749
      RTHR=(VALUE(22)+VALUE(23))/3600.
      IF(RTHR.LT.1.) GO TO 505
          RTHR=1.
505  IF((IN .GT. 9) .AND. (IN .LT.18)) GO TO 600
      NLOAD(I)=NLOAD(I)+VALUE(37)/1000.
      GO TO 749
600  DLOAD(I)=DLOAD(I)+VALUE(37)/1000.
749  IF(IN.LT.24) GO TO 750
      IN=0
750  CONTINUE
      CLOSE(UNIT=43)
      GO TO 800
801  DO 805 I=1,21
          IF(DHOURLS(I).EQ.0.) GO TO 802
          DLOAD(I)=3.413*DLOAD(I)/DHOURLS(I)
802  IF(NHOURLS(I).EQ.0.) GO TO 803
          NLOAD(I)=3.413*NLOAD(I)/NHOURLS(I)
803  IF(SUMHR(I).EQ.0.) GO TO 805
          AVGDB(I)=SUMDB(I)/SUMHR(I)
          AVGRH(I)=SUMRH(I)/SUMHR(I)
805  CONTINUE
      WRITE(45,807) FNAME,IHOURS
807  FORMAT(' FOR THE WEEK OF ',A5,' AND IHOURS=',I3,
      $' THE RESULTS ARE:  ')
      WRITE(45,808)
808  FORMAT(1X)
      WRITE(45,810)
810  FORMAT(3X,'I',5X,'DLOAD',4X,'DHOURLS',5X,'NLOAD',4X,'NHOURLS',
      $5X,'AVGDB',5X,'AVGRH')
      DO 825 I=1,21
          WRITE(45,820) I,DLOAD(I),DHOURLS(I),NLOAD(I),NHOURLS(I),
      $AVGDB(I),AVGRH(I)

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820     FORMAT(2X,I2,2X,F8.2,2X,F8.2,2X,F8.2,2X,F8.2,2X,F8.2,2X,
$F8.2)
825     CONTINUE
      WRITE(45,840)
840     FORMAT(1X)
      WRITE(45,850) IHRSGD
850     FORMAT(2X,'HOURS OF GOOD DATA=',I4)
      TLOAD=0.
      DO 920 I=1,21
        DLOAD(I)=DLOAD(I)*DHOURS(I)
        NLOAD(I)=NLOAD(I)*NHOURS(I)
909     TLOAD=TLOAD+DLOAD(I)+NLOAD(I)
920     CONTINUE
      WRITE(45,938)
938     FORMAT(1X)
      WRITE(45,948) TLOAD
948     FORMAT(2X,'TOTAL LOAD IN KBTU=',F8.2)
      STOP
      END

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B.6 Cooling Season Load Manipulation Computer Program for the Single-Speed Mode

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C
C   THE FOLLOWING PROGRAM SUMS UP THE DAY AND NIGHT COOLING
C   LOADS ALONG WITH THE NUMBER OF OPERATING HOURS FOR BOTH
C   DAY AND NIGHT. OUTPUT IS IN FARENHEIT TEMPERATURE BINS.
C   ALSO, IT COUNTS THE NUMBER OF GOOD DATA HOURS FOR EACH
C   SET OF DATA.
C
      REAL VALUE(40),DLOTOT(11),DLolat(11),NLOTOT(11),NLolat(11)
      REAL DHOurs(11),NHOurs(11),TEMPF,RTHR,TLOAD
      OPEN(UNIT=45,FILE='JC2.DAT')
101  OPEN(UNIT=44,FILE='NUT2.DAT')
      WRITE(5,100)
100  FORMAT(' WHAT IS THE INPUT FILE')
      READ (5,110) FNAME
110  FORMAT(A5)
      WRITE(5,120) FNAME
120  FORMAT(' FOR THE WEEK',A6,' HOW MANY HOURS WILL BE AVAILABLE')
      READ(5,130) IHOurs
130  FORMAT(I3)
      DO 135 I=1,11
          DLOTOT(I)=0.
          DLolat(I)=0.
          DHOurs(I)=0.
          NLOTOT(I)=0.
          NLolat(I)=0.
          NHOurs(I)=0.
135  CONTINUE
      IHRSGD=0
800  READ(44,200) TLOW,THIGH,I
200  FORMAT(2X,F8.2,2X,F8.2,2X,I2)
      IF(TLOW.EQ.843.00) CLOSE(UNIT=44)
      IF(TLOW.EQ.843.00) GO TO 801
      OPEN(UNIT=43,FILE=FNAME)
      IN=0
      DO 750 II=1,IHOurs
          IN=IN+1
          READ(43,300) (VALUE(J),J=1,40)
300  FORMAT(8F10.4)
          DO 320 K=1,40
              IF(VALUE(K).EQ.99999) GO TO 749
320  CONTINUE
          TEMPF=1.80*VALUE(33)+32.0
          IF((TEMPF .LT. TLOW) .OR. (TEMPF .GE. THIGH)) GO TO 749
          IF(VALUE(23).GT.12.) GO TO 749
          IHRSGD=IHRSGD+1
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      IF((IN .GT. 9) .AND. (IN .LT. 18)) GO TO 400
      NHOURS(I)=NHOURS(I)+1.
      GO TO 449
400    DHOURL(I)=DHOURL(I)+1.
449    IF(VALUE(2).LT.16.0) GO TO 749
      RTHR=(VALUE(22)+VALUE(23))/3600.
      IF(RTHR.LT.1.) GO TO 505
          RTHR=1.0
505    IF((IN .GT. 9) .AND. (IN .LT. 18)) GO TO 600
      NLOTOT(I)=NLOTOT(I)+VALUE(38)/1000.
      NLOLAT(I)=NLOLAT(I)+VALUE(39)/1000.
      GO TO 749
600    DLOTOT(I)=DLOTOT(I)+VALUE(38)/1000.
      DLOLAT(I)=DLOLAT(I)+VALUE(39)/1000.
749    IF(IN.LT.24) GO TO 750
      IN=0
750    CONTINUE
      CLOSE(UNIT=43)
      GO TO 800
801    DO 805 I=1,11
          IF(DHOURL(I).EQ.0.) GO TO 802
          DLOTOT(I)=3.413*DLOTOT(I)/DHOURL(I)
          DLOLAT(I)=3.413*DLOLAT(I)/DHOURL(I)
802    IF(NHOURL(I).EQ.0.) GO TO 805
          NLOTOT(I)=3.413*NLOTOT(I)/NHOURL(I)
          NLOLAT(I)=3.413*NLOLAT(I)/NHOURL(I)
805    CONTINUE
      WRITE(45,807) FNAME,IHOURS
807    FORMAT(' FOR THE WEEK OF ',A5,' AND IHOURS=',I3,' THE RESULTS
$ARE: ')
      WRITE(45,808)
808    FORMAT(1X)
      WRITE(45,810)
810    FORMAT(3X,'I',5X,'DLOTOT',4X,'DLOLAT',4X,'DHOURL',3X,'NLOTOT',
$4X,'NLOLAT',4X,'NHOURL')
      DO 825 I=1,11
          WRITE(45,820) I,DLOTOT(I),DLOLAT(I),DHOURL(I),NLOTOT(I),
$NLOLAT(I),NHOURL(I)
820    FORMAT(2X,I2,6(2X,F8.2))
825    CONTINUE
      WRITE(45,840)
840    FORMAT(1X)
      WRITE(45,850) IHRSGD
850    FORMAT(2X,'HOURS OF GOOD DATA=',I4)
      TLOAD=0.
      DO 920 I=1,11
          DLOTOT(I)=DLOTOT(I)*DHOURL(I)
          NLOTOT(I)=NLOTOT(I)*NHOURL(I)
          TLOAD=TLOAD+DLOTOT(I)+NLOTOT(I)
920    CONTINUE

```

```
      WRITE(45,938)
938   FORMAT(1X)
      WRITE(45,948) TLOAD
948   FORMAT(2X,'TOTAL LOAD IN KBTU=',F8.2)
      STOP
      END
```

B.7 Cooling Season Load Manipulation Computer Program for the Dual-Speed Mode

```

C
C   THE FOLLOWING PROGRAM SUMS UP THE DAY AND NIGHT COOLING
C   LOADS ALONG WITH THE NUMBER OF OPERATING HOURS FOR BOTH
C   DAY AND NIGHT. OUTPUT IS IN FARENHEIT TEMPERATURE BINS.
C   ALSO, IT COUNTS THE NUMBER OF GOOD DATA HOURS FOR EACH
C   SET OF DATA.
C
      REAL VALUE(40),DLOTOT(11),DLolat(11),NLOTOT(11),NLolat(11)
      REAL DHOURS(11),NHOURS(11),TEMPF,RTHR,TLOAD
      OPEN(UNIT=45,FILE='JC2.DAT')
101  OPEN(UNIT=44,FILE='NUT2.DAT')
      WRITE(5,100)
100  FORMAT(' WHAT IS THE INPUT FILE')
      READ (5,110) FNAME
110  FORMAT(A5)
      WRITE(5,120) FNAME
120  FORMAT(' FOR THE WEEK',A6,' HOW MANY HOURS WILL BE AVAILABLE')
      READ(5,130) IHOURS
130  FORMAT(I3)
      DO 135 I=1,11
          DLOTOT(I)=0.
          DLolat(I)=0.
          DHOURS(I)=0.
          NLOTOT(I)=0.
          NLolat(I)=0.
          NHOURS(I)=0.
135  CONTINUE
      IHRSGD=0
800  READ(44,200) TLOW,THIGH,I
200  FORMAT(2X,F8.2,2X,F8.2,2X,I2)
      IF(TLOW.EQ.843.00) CLOSE(UNIT=44)
      IF(TLOW.EQ.843.00) GO TO 801
      OPEN(UNIT=43,FILE=FNAME)
      IN=0
      DO 750 II=1,IHOURS
          IN=IN+1
          READ(43,300) (VALUE(J),J=1,40)
300  FORMAT(8F10.4)
          DO 320 K=1,40
              IF(VALUE(K).EQ.99999) GO TO 749
320  CONTINUE
          TEMPF=1.80*VALUE(33)+32.0
          IF((TEMPF .LT. TLOW) .OR. (TEMPF .GE. THIGH)) GO TO 749
C      IF(VALUE(23).GT.12.) GO TO 749
      IHRSGD=IHRSGD+1

```

```

      IF((IN .GT. 9) .AND. (IN .LT. 18)) GO TO 400
      NHOURS(I)=NHOURS(I)+1.
      GO TO 449
400    DHOURLS(I)=DHOURLS(I)+1.
449    IF(VALUE(2).LT.16.0) GO TO 749
      RTHR=(VALUE(22)+VALUE(23))/3600.
      IF(RTHR.LT.1.) GO TO 505
          RTHR=1.0
505    IF((IN .GT. 9) .AND. (IN .LT. 18)) GO TO 600
      NLOTOT(I)=NLOTOT(I)+VALUE(38)/1000.
      NLOLAT(I)=NLOLAT(I)+VALUE(39)/1000.
      GO TO 749
600    DLOTOT(I)=DLOTOT(I)+VALUE(38)/1000.
      DLOLAT(I)=DLOLAT(I)+VALUE(39)/1000.
749    IF(IN.LT.24) GO TO 750
      IN=0
750    CONTINUE
      CLOSE(UNIT=43)
      GO TO 800
801    DO 805 I=1,11
          IF(DHOURLS(I).EQ.0.) GO TO 802
          DLOTOT(I)=3.413*DLOTOT(I)/DHOURLS(I)
          DLOLAT(I)=3.413*DLOLAT(I)/DHOURLS(I)
802    IF(NHOURLS(I).EQ.0.) GO TO 805
          NLOTOT(I)=3.413*NLOTOT(I)/NHOURLS(I)
          NLOLAT(I)=3.413*NLOLAT(I)/NHOURLS(I)
805    CONTINUE
      WRITE(45,807) FNAME,IHOURS
807    FORMAT(' FOR THE WEEK OF ',A5,' AND IHOURS=',I3,' THE RESULTS
$ARE: ')
      WRITE(45,808)
808    FORMAT(1X)
      WRITE(45,810)
810    FORMAT(3X,'I',5X,'DLOTOT',4X,'DLOLAT',4X,'DHOURLS',3X,'NLOTOT',
$4X,'NLOLAT',4X,'NHOURLS')
      DO 825 I=1,11
          WRITE(45,820) I,DLOTOT(I),DLOLAT(I),DHOURLS(I),NLOTOT(I),
$NLOLAT(I),NHOURLS(I)
820    FORMAT(2X,I2,6(2X,F8.2))
825    CONTINUE
      WRITE(45,840)
840    FORMAT(1X)
      WRITE(45,850) IHRSGD
850    FORMAT(2X,'HOURS OF GOOD DATA=',I4)
      TLOAD=0.
      DO 920 I=1,11
          DLOTOT(I)=DLOTOT(I)*DHOURLS(I)
          NLOTOT(I)=NLOTOT(I)*NHOURLS(I)
          TLOAD=TLOAD+DLOTOT(I)+NLOTOT(I)
920    CONTINUE

```

```
      WRITE(45,938)
938   FORMAT(1X)
      WRITE(45,948) TLOAD
948   FORMAT(2X,'TOTAL LOAD IN KBTU=',F8.2)
      STOP
      END
```

B.8 Single-Speed Mode BLOCK Subroutine Calender Information

C

C CALENDAR INFORMATION

C

```
DATA MON/'JAN ','FEB ','MAR ','APR ','MAY ','JUN ','JUL ',  
&      'AUG ','SEP ','OCT ','NOV ','DEC '/  
DATA TH/336.,260.,288.,120.,0.,168.,325.,370.,  
&      180.,0.,0.,190.,  
DATA NMN/1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12/
```

C

B.9 Dual-Speed Mode BLOCK Subroutine Calender Information

C

C CALENDAR INFORMATION

C

```
DATA MON/'JAN ','FEB ','MAR ','APR ','MAY ','JUN ','JUL ',  
&      'AUG ','SEP ','OCT ','NOV ','DEC '/  
DATA TH/158.,240.,384.,168.,0.,254.,184.,264.,  
&      261.,0.,0.,240.,  
DATA NMN/1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12/
```

C

B.10 Dual-Speed Mode SSTATE Subroutine Sample Listing

```

SUBROUTINE SSTATE(NCAP)
C
C   REAL LFDPOW, LFD CAP, LFD COP
C
COMMON/ FRDFAC / DB, WB, COP, CAP, COPFR, CAPFR,
&          LFDPOW, LFD COP, LFD CAP
C
COMMON/ PARSIT / PARON(10,2), PAROFF, TMPOFF, PARCAP(10,2),
&          PARCOP(10,2), PARONL(10,2), PARONS, PARONR,
&          OFFPRB, ETACNV, CNVFC1, CNVFC2, MPARCY,
&          MTRNOF, IMODE
C
COMMON/ SPEED / SPEED
C
COMMON/ SS / TMPSS(10,2), POWSS(10,10,2), COPSS(10,10,2),
&          CAPSS(10,10,2), SPDRAT(10,2), HPUMP(20),
&          NSPDS(2), NTMPSS(2), MTYINP, MCAPMD, MPOWIN
C
C   COMPUTE STEADY-STATE CAPACITY AND POWER AT SPECIFIC BIN
C   TEMPERATURE
C
      IF(NCAP.NE.-1) SPEED = SPDRAT(NCAP,IMODE)
      CAP = SLAG(DB,SPEED,TMPSS(1,IMODE),SPDRAT(1,IMODE),CAPSS(1,1,
&
IMODE),NTMPSS(IMODE),NSPDS(IMODE),3,IEXTX,IEXTY,10)
      POW = SLAG(DB,SPEED,TMPSS(1,IMODE),SPDRAT(1,IMODE),POWSS(1,1,
&
IMODE),NTMPSS(IMODE),NSPDS(IMODE),3,IEXTX,IEXTY,10)
C
C   COMPUTE COP AT SPECIFIC BIN TEMPERATURE
C
      IF(IMODE.EQ.1.AND.NCAP.EQ.1.AND.DB.LT.32.) CAP=0.0
      MCAPMD=3
      IF(IMODE.EQ.1) MCAPMD=2
C
      IF(CAP.LT.0.0) CAP = 0.0
      IF(POW.LE.0.0) POW = 0.0001
      COP = CAP/(POW*3.413/CNVFC1)
      IF(MTYINP.EQ.1.AND.COP.LT.1.0) COP = 1.0
      IF(MTYINP.EQ.2.AND.COP.LE.0.0) COP = 0.01
C
C   COMPUTE FROST/DEFROST LOSSES
C
      CALL FRDEFR(IMODE,ETACNV,MTYINP,NCAP)
C

```

```
PARONS = PARONL(NCAP,IMODE)
PARONR = LFDPOW*PARONS
C
RETURN
END
```

B.11 Single-Speed Mode HVAC/Loads Data File Results

INPUT SUMMARY:

ELECTRIC-DRIVEN HEAT PUMP

SAMPLE RUN OF A LENNOX 2-SPEED WITH HIGH SPEED COMPRESSOR OPERATION ONLY

***** SUMMARY OF HEATING PERFORMANCE DATA:

LENNOX(2-SPEED) HP14 LEGEND II SERIES--HP14-261/411V W CP12-41V/E12Q3
(NO CAPACITY MODULATION)

*** STEADY-STATE DATA:

PT	AMBIENT TEMPERATURE (F)	STEADY-STATE POWER (KWH)	PT	AMBIENT TEMPERATURE (F)	STEADY-STATE CAPACITY (KBTUH)
1	-15.00	1.490	1	-15.00	7.60
2	5.00	1.940	2	5.00	14.80
3	15.00	2.100	3	15.00	19.30
4	25.00	2.330	4	25.00	23.77
5	35.00	2.580	5	35.00	29.29
6	45.00	2.840	6	45.00	34.00
7	50.00	2.980	7	50.00	36.70
8	55.00	3.130	8	55.00	39.46
9	60.00	3.260	9	60.00	42.09
10	65.00	3.400	10	65.00	44.60

*** CYCLING LOSS DATA:

CD = 0.200

*** FROST/DEFROST DATA:

ORNL TUBE & PLATE FIN, FROSTING/RECOVERY DATA USED

FROST INITIATION POINT = 42.00 DEG F

DEFROST TEMPERING HEAT = 10.00 KW

DEFROST COOLING CAPACITY GIVEN BY ORNL WAVY FIN DATA

DEFROST COOLING COP GIVEN BY ORNL WAVY FIN DATA

DEFROST LENGTH AND

TIME BETWEEN DEFROSTS GIVEN BY ORNL WAVY FIN DATA

*** ON-TIME PARASITIC DATA:

ON-TIME PARASITIC POWER IS 835.00 WATTS TIMES THE FRACTIONAL ON TIME.
 AMOUNT OF ON-TIME PARASITICS ADDED TO S-S CAPACITY VALUES IS 0.00 WATTS
 AMOUNT OF ON-TIME PARASITICS ADDED TO S-S COP VALUES IS 835.00 WATTS

***** SUMMARY OF COOLING PERFORMANCE DATA:

LENNOX(2-SPEED) HP14 LEGEND II SERIES--HP14-261/411V W CP12-41V/E12Q3

(NO CAPACITY MODULATION)

*** STEADY-STATE DATA:

PT	AMBIENT TEMPERATURE	STEADY-STATE POWER	PT	AMBIENT TEMPERATURE	STEADY-STATE CAPACITY
	(F)	(KWH)		(F)	(KBTUH)
1	75.00	3.170	1	75.00	28.53
2	85.00	3.340	2	85.00	27.52
3	95.00	3.500	3	95.00	26.50
4	105.00	3.660	4	105.00	25.49

*** CYCLING LOSS DATA:

CD = 0.130

*** ON-TIME PARASITIC DATA:

ON-TIME PARASITIC POWER IS 835.00 WATTS TIMES THE FRACTIONAL ON TIME.
AMOUNT OF ON-TIME PARASITICS ADDED TO S-S CAPACITY VALUES IS 0.00 WATTS
AMOUNT OF ON-TIME PARASITICS ADDED TO S-S COP VALUES IS 835.00 WATTS

***** MODE AND MODULATION INDEPENDENT HEAT PUMP DATA:

*** OFF-TIME PARASITIC DATA:

OFF-TIME PARASITIC POWER IS 0.00 WATTS TIMES THE FRACTIONAL OFF TIME.

*** UNIT SIZE SCALING:

THE INPUT CAPACITY, POWER, AND PARASITIC VALUES WERE NOT SCALED

***** HOUSE, WEATHER, AND LOADS INFORMATION:

167 M**2 RANCH, TECH HOUSE 3
THE HOUSE HAS 1800. SQUARE FEET OF FLAT ROOF AREA WITH
R-38. CEILING AND
R-19. WALLS

WEATHER FOR NOXVILLE, TN

WINTER INDOOR TEMPERATURE SETTING - DB = 70.00 F
SUMMER INDOOR TEMPERATURE SETTING - DB = 78.00 F
SUMMER INDOOR TEMPERATURE SETTING - WB = 67.00 F

99.0% DESIGN DAY TEMPERATURE--HEATING = 13.00 F
97.5% DESIGN DAY TEMPERATURE--COOLING = 92.00 F

DESIGN HEATING LOAD = 30.00 KBTU/HR
DESIGN COOLING LOAD = 22.00 KBTU/HR

COOLING SEASON SENSIBLE-TO-TOTAL COOLING LOAD RATIOS
BY AMBIENT TEMPERATURE BINS --

AMBIENT TEMP (F)	52.0	57.0	62.0	67.0	72.0	77.0	82.0	87.0	92.0	97.0
S/T RATIO	1.000	0.462	0.747	0.741	0.737	0.735	0.745	0.752	0.763	0.790

1PERFORMANCE CALCULATIONS:

SAMPLE RUN OF A LENNOX 2-SPEED WITH HIGH SPEED COMPRESSOR OPERATION ONLY

LENNOX(2-SPEED) HP14 LEGEND II SERIES--HP14-261/411V W CP12-41V/E12Q3
167 M***2 RANCH, TECH HOUSE 3
NOXVILLE, TN

0*** HEATING SEASON CALCULATIONS: (NO CAPACITY MODULATION)

MDPT	AVE	COP			CAP			% ON	DEMAND	BACKUP	ENERGY	ENERGY
TEMP	HRS	LOAD	S-S	F/D	F/D/C	S-S	F/D	TIME	RATE	I2R	IN	OUT
(F)		(KBTUH)							(KW)	(KWH)	(KWH)	(KBTU)
7.	6.	24.57	1.63	1.63	1.63	15.65	15.65	100.	12.81	15.7	32.5	147.4
12.	36.	25.77	1.81	1.82	1.82	17.89	18.27	100.	12.93	79.1	184.7	927.7
17.	62.	23.70	1.99	1.98	1.98	20.20	20.24	100.	13.00	62.8	248.5	1469.3
22.	54.	21.31	2.13	2.11	2.08	22.43	22.43	96.	3.12	0.0	161.8	1150.7
27.	137.	17.44	2.26	2.20	2.07	24.79	24.92	74.	3.32	0.0	338.4	2389.5
32.	163.	14.07	2.42	2.34	2.10	27.52	28.29	55.	3.55	0.0	319.9	2293.5
37.	195.	13.25	2.56	2.45	2.16	30.30	31.62	47.	3.78	0.0	349.6	2582.8
42.	108.	8.28	2.66	2.66	2.26	32.67	32.67	30.	3.60	0.0	115.7	894.0
47.	68.	3.13	2.75	2.75	2.25	35.05	35.05	11.	3.73	0.0	27.7	212.9
52.	68.	2.03	2.86	2.86	2.32	37.80	37.80	7.	3.87	0.0	17.4	137.9
57.	70.	1.06	2.95	2.95	2.38	40.53	40.53	3.	4.02	0.0	9.1	74.0
62.	88.	0.63	3.04	3.04	2.44	43.11	43.11	2.	4.15	0.0	6.7	55.7
67.	85.	0.16	3.11	3.11	2.49	45.60	45.60	0.	4.29	0.0	1.6	13.6
72.	40.	0.12	3.18	3.18	2.55	48.11	48.11	0.	4.43	0.0	0.6	4.9

*** HEATING SEASON PERFORMANCE SUMMARY:

SEASONAL ENERGY INPUT	1814.2 KWH	BACKUP I2R ENERGY	157.6 KWH
SEASONAL ENERGY OUTPUT	12353.8 KBTU	PARASITIC ENERGY	0.0 KWH
SEASONAL PERFORMANCE FACTOR	1.995	HOURS OF OPERATION	488.9 HRS
		I2R TEMPERING ENERGY	49.0 KWH
		DEFROST HP ENERGY	11.6 KWH
		TOTAL DEFROST TIME	4.9 HRS
		NUMBER OF DEFROSTS	50.5

0*** SEASONAL ENERGY USE BREAKDOWN:

0-- DYNAMIC LOSS BREAKDOWN --

OFROSTING/DEFROSTING LOSSES -

DIRECT FROSTING/DEFROSTING ENERGY LOSS 35.9 KWH

INDIRECT CHANGE

IN BACKUP HEAT REQUIREMENTS -4.8 KWH

IN CYCLING LOSSES	6.0 KWH
IN PARASITICS	0.0 KWH

SEASONAL ENERGY LOSS DUE TO FROSTING/DEFROSTING	37.0 KWH
OCYCLING LOSSES -	
DIRECT CYCLING ENERGY LOSS	117.9 KWH
INDIRECT CHANGE	
IN PARASITICS	0.0 KWH

SEASONAL ENERGY LOSS DUE TO CYCLING	117.9 KWH
0-- USE AND LOSS SUMMARY --	
OSTEADY-STATE ENERGY USE -	
BASE TOTAL, EXCLUDING BACKUP HEAT AND PARASITICS	1496.9 KWH (82.5%)
BACKUP HEAT REQUIREMENTS	162.4 KWH (9.0%)
ON-TIME PARASITICS	0.0 KWH (0.0%)
OFF-TIME PARASITICS	0.0 KWH (0.0%)
ODYNAMIC LOSSES -	
FROSTING/DEFROSTING	37.0 KWH (2.0%)
CYCLING	117.9 KWH (6.5%)

TOTAL ENERGY USE FOR THE SEASON	1814.2 KWH (100.0%)

1PERFORMANCE CALCULATIONS:

SAMPLE RUN OF A LENNOX 2-SPEED WITH HIGH SPEED COMPRESSOR OPERATION ONLY

LENNOX(2-SPEED) HP14 LEGEND II SERIES--HP14-261/411V W CP12-41V/E12Q3
167 M**2 RANCH, TECH HOUSE 3
NOXVILLE, TN

0*** COOLING SEASON CALCULATIONS: (NO CAPACITY MODULATION)

MDPT	AVE	COP			CAP			% ON	DEMAND	BACKUP	ENERGY	ENERGY
TEMP	HRS	LOAD	S-S	F/D	F/D/C	S-S	F/D	TIME	RATE	I2R	IN	OUT
(F)		(KBTUH)							(KW)	(KWH)	(KWH)	(KBTU)
57.	28.	0.05	2.40	2.40	2.09	30.35	30.35	0.	3.70	0.0	0.2	1.3
62.	76.	1.40	2.31	2.31	2.02	29.84	29.84	5.	3.78	0.0	15.4	106.2
67.	235.	3.54	2.22	2.22	1.97	29.34	29.34	14.	3.87	0.0	123.8	831.5
72.	265.	5.76	2.14	2.14	1.91	28.83	28.83	22.	3.95	0.0	233.7	1527.1
77.	149.	9.05	2.05	2.05	1.87	28.33	28.33	35.	4.04	0.0	210.9	1347.9
82.	149.	11.68	1.98	1.98	1.83	27.82	27.82	45.	4.13	0.0	279.0	1739.9
87.	98.	12.35	1.90	1.90	1.77	27.32	27.32	49.	4.21	0.0	200.8	1210.8
92.	28.	13.53	1.83	1.83	1.71	26.81	26.81	54.	4.29	0.0	64.8	378.9
97.	2.	15.62	1.76	1.76	1.67	26.30	26.30	63.	4.37	0.0	5.5	31.2

*** COOLING SEASON PERFORMANCE SUMMARY:		SEASONAL ENERGY INPUT	1134.0 KWH
BACKUP I2R ENERGY	0.0 KWH		
SEASONAL ENERGY OUTPUT	7174.8 KBTU	PARASITIC ENERGY	0.0 KWH
SEASONAL PERFORMANCE FACTOR	1.854	HOURS OF OPERATION	279.1 HRS

0*** SEASONAL ENERGY USE BREAKDOWN:

0-- DYNAMIC LOSS BREAKDOWN --

0CYCLING LOSSES -

DIRECT CYCLING ENERGY LOSS	98.9 KWH
INDIRECT CHANGE	
IN PARASITICS	0.0 KWH

SEASONAL ENERGY LOSS DUE TO CYCLING	98.9 KWH
-------------------------------------	----------

0-- USE AND LOSS SUMMARY --

0STEADY-STATE ENERGY USE -

BASE TOTAL, EXCLUDING BACKUP HEAT AND PARASITICS	1035.2 KWH (91.3%)
BACKUP HEAT REQUIREMENTS	0.0 KWH (0.0%)
ON-TIME PARASITICS	0.0 KWH (0.0%)
OFF-TIME PARASITICS	0.0 KWH (0.0%)

0DYNAMIC LOSSES -

FROSTING/DEFROSTING	0.0 KWH (0.0%)
CYCLING	98.9 KWH (8.7%)

TOTAL ENERGY USE FOR THE SEASON	1134.0 KWH (100.0%)
---------------------------------	---------------------

1PERFORMANCE CALCULATIONS:

SAMPLE RUN OF A LENNOX 2-SPEED WITH HIGH SPEED COMPRESSOR OPERATION ONLY

LENNOX(2-SPEED) HP14 LEGEND II SERIES--HP14-261/411V W CP12-41V/E12Q3
167 M***2 RANCH, TECH HOUSE 3
NOXVILLE, TN

*** ANNUAL PERFORMANCE SUMMARY:

0ANNUAL ENERGY INPUT	2948.2 KWH	BACKUP I2R ENERGY	157.6 KWH
ANNUAL ENERGY OUTPUT	19528.6 KBTU	PARASITIC ENERGY	0.0 KWH
ANNUAL PERFORMANCE FACTOR	1.941	HOURS OF OPERATION	768.0 HRS

I2R TEMPERING ENERGY	49.0 KWH
DEFROST HP ENERGY	11.6 KWH
TOTAL DEFROST TIME	4.9 HRS
NUMBER OF DEFROSTS	50.5

0*** ANNUAL ENERGY USE BREAKDOWN:

0-- DYNAMIC LOSS BREAKDOWN --

0FROSTING/DEFROSTING LOSSES -

DIRECT FROSTING/DEFROSTING ENERGY LOSS	35.9 KWH
--	----------

INDIRECT CHANGE

IN BACKUP HEAT REQUIREMENTS	-4.8 KWH
-----------------------------	----------

IN CYCLING LOSSES	6.0 KWH
-------------------	---------

IN PARASITICS	0.0 KWH
---------------	---------

ANNUAL ENERGY LOSS DUE TO FROSTING/DEFROSTING	37.0 KWH
---	----------

0CYCLING LOSSES -

DIRECT CYCLING ENERGY LOSS	216.7 KWH
----------------------------	-----------

INDIRECT CHANGE	
-----------------	--

IN PARASITICS	0.0 KWH
---------------	---------

ANNUAL ENERGY LOSS DUE TO CYCLING	216.7 KWH
-----------------------------------	-----------

0-- USE AND LOSS SUMMARY --

0STEADY-STATE ENERGY USE -

BASE TOTAL, EXCLUDING BACKUP HEAT AND PARASITICS	2532.0 KWH (85.9%)
--	---------------------

BACKUP HEAT REQUIREMENTS	162.4 KWH (5.5%)
--------------------------	-------------------

ON-TIME PARASITICS	0.0 KWH (0.0%)
--------------------	-----------------

OFF-TIME PARASITICS	0.0 KWH (0.0%)
---------------------	-----------------

0DYNAMIC LOSSES -

FROSTING/DEFROSTING	37.0 KWH (1.3%)
---------------------	------------------

CYCLING	216.7 KWH (7.4%)
---------	-------------------

TOTAL ENERGY USE FOR THE YEAR	2948.2 KWH (100.0%)
-------------------------------	---------------------

B.12 Dual-Speed Mode HVAC/Loads Data File Results (SOT=47°F)

INPUT SUMMARY:

ELECTRIC-DRIVEN HEAT PUMP

SAMPLE RUN OF A LENNOX TWO-SPEED WITH LOW-SPEED LOCKOUT IN HEATING

***** SUMMARY OF HEATING PERFORMANCE DATA:

LENNOX(2-SPEED) HP14 LEGEND II SERIES--HP14-261/411V W CP12-41V/E12Q3
(STEP CAPACITY MODULATION ALTERNATING TWO CAPACITY LEVELS
AT APPROPRIATE AMBIENTS)

----- HEATING MODE DATA FOR -----
----- MODULATION RATIO OF 0.50 -----

*** STEADY-STATE DATA:

PT	AMBIENT TEMPERATURE (F)	STEADY-STATE POWER (KWH)	PT	AMBIENT TEMPERATURE (F)	STEADY-STATE CAPACITY (KBTUH)
1	-15.00	.010	1	-15.00	0.00
2	5.00	.010	2	5.00	0.00
3	15.00	.010	3	15.00	0.00
4	25.00	1.140	4	25.00	14.12
5	35.00	1.220	5	35.00	17.76
6	45.00	1.310	6	45.00	21.40
7	50.00	1.350	7	50.00	23.20
8	55.00	1.400	8	55.00	25.10
9	60.00	1.440	9	60.00	26.80
10	65.00	1.480	10	65.00	28.70

*** CYCLING LOSS DATA:

CD = 0.220

*** FROST/DEFROST DATA:

ORNL TUBE & PLATE FIN, FROSTING/RECOVERY DATA USED

FROST INITIATION POINT = 37.00 DEG F

DEFROST TEMPERING HEAT = 10.00 KW

DEFROST COOLING CAPACITY GIVEN BY ORNL WAVY FIN DATA
DEFROST COOLING COP GIVEN BY ORNL WAVY FIN DATA

DEFROST LENGTH AND
TIME BETWEEN DEFROSTS GIVEN BY ORNL WAVY FIN DATA

*** ON-TIME PARASITIC DATA:

ON-TIME PARASITIC POWER IS 835.00 WATTS TIMES THE FRACTIONAL ON TIME.
AMOUNT OF ON-TIME PARASITICS ADDED TO S-S CAPACITY VALUES IS 0.00 WATTS
AMOUNT OF ON-TIME PARASITICS ADDED TO S-S COP VALUES IS 835.00 WATTS

----- HEATING MODE DATA FOR -----
----- MODULATION RATIO OF 1.00 -----

*** STEADY-STATE DATA:

PT	AMBIENT TEMPERATURE (F)	STEADY-STATE POWER (KWH)	PT	AMBIENT TEMPERATURE (F)	STEADY-STATE CAPACITY (KBTUH)
1	-15.00	1.490	1	-15.00	7.60
2	5.00	1.940	2	5.00	14.80
3	15.00	2.100	3	15.00	19.30
4	25.00	2.330	4	25.00	23.77
5	35.00	2.580	5	35.00	29.29
6	45.00	2.840	6	45.00	34.00
7	50.00	2.980	7	50.00	36.70
8	55.00	3.130	8	55.00	39.46
9	60.00	3.260	9	60.00	42.09
10	65.00	3.400	10	65.00	44.60

*** CYCLING LOSS DATA:

CD = 0.200

*** FROST/DEFROST DATA:

ORNL TUBE & PLATE FIN, FROSTING/RECOVERY DATA USED

FROST INITIATION POINT = 42.00 DEG F
DEFROST TEMPERING HEAT = 10.00 KW

DEFROST COOLING CAPACITY GIVEN BY ORNL WAVY FIN DATA
DEFROST COOLING COP GIVEN BY ORNL WAVY FIN DATA

DEFROST LENGTH AND
TIME BETWEEN DEFROSTS GIVEN BY ORNL WAVY FIN DATA

*** ON-TIME PARASITIC DATA:

ON-TIME PARASITIC POWER IS 835.00 WATTS TIMES THE FRACTIONAL ON TIME.
AMOUNT OF ON-TIME PARASITICS ADDED TO S-S CAPACITY VALUES IS 0.00 WATTS
AMOUNT OF ON-TIME PARASITICS ADDED TO S-S COP VALUES IS 835.00 WATTS

***** SUMMARY OF COOLING PERFORMANCE DATA:

LENNOX(2-SPEED) HP14 LEGEND II SERIES--HP14-261/411V W CP12-41V/E12Q3
(STEP CAPACITY MODULATION ALTERNATING TWO CAPACITY LEVELS
AT APPROPRIATE AMBIENTS)

----- COOLING MODE DATA FOR -----
----- MODULATION RATIO OF 0.50 -----

*** STEADY-STATE DATA:

PT	AMBIENT TEMPERATURE (F)	STEADY-STATE POWER (KWH)	PT	AMBIENT TEMPERATURE (F)	STEADY-STATE CAPACITY (KBTUH)
1	75.00	1.360	1	75.00	18.32
2	85.00	1.440	2	85.00	18.01
3	95.00	1.560	3	95.00	17.70
4	105.00	1.680	4	105.00	17.40

*** CYCLING LOSS DATA:

CD = 0.130

*** ON-TIME PARASITIC DATA:

ON-TIME PARASITIC POWER IS 835.00 WATTS TIMES THE FRACTIONAL ON TIME.
AMOUNT OF ON-TIME PARASITICS ADDED TO S-S CAPACITY VALUES IS 0.00 WATTS

AMOUNT OF ON-TIME PARASITICS ADDED TO S-S COP VALUES IS 835.00 WATTS

----- COOLING MODE DATA FOR -----
----- MODULATION RATIO OF 1.00 -----

*** STEADY-STATE DATA:

PT	AMBIENT TEMPERATURE (F)	STEADY-STATE POWER (KWH)	PT	AMBIENT TEMPERATURE (F)	STEADY-STATE CAPACITY (KBTUH)
1	75.00	3.170	1	75.00	28.53
2	85.00	3.340	2	85.00	27.52
3	95.00	3.500	3	95.00	26.50
4	105.00	3.660	4	105.00	25.49

*** CYCLING LOSS DATA:

CD = 0.130

*** ON-TIME PARASITIC DATA:

ON-TIME PARASITIC POWER IS 835.00 WATTS TIMES THE FRACTIONAL ON TIME.
AMOUNT OF ON-TIME PARASITICS ADDED TO S-S CAPACITY VALUES IS 0.00 WATTS
AMOUNT OF ON-TIME PARASITICS ADDED TO S-S COP VALUES IS 835.00 WATTS

***** MODE AND MODULATION INDEPENDENT HEAT PUMP DATA:

*** OFF-TIME PARASITIC DATA:

OFF-TIME PARASITIC POWER IS 0.00 WATTS TIMES THE FRACTIONAL OFF TIME.

*** UNIT SIZE SCALING:

THE INPUT CAPACITY, POWER, AND PARASITIC VALUES WERE NOT SCALED

***** HOUSE, WEATHER, AND LOADS INFORMATION:

167**2 RANCH, TECH HOUSE 3
 THE HOUSE HAS 1800. SQUARE FEET OF FLAT ROOF AREA WITH
 R-38. CEILING AND
 R-19. WALLS

WEATHER FOR NOXVILLE, TN

WINTER INDOOR TEMPERATURE SETTING - DB = 70.00 F
 SUMMER INDOOR TEMPERATURE SETTING - DB = 78.00 F
 SUMMER INDOOR TEMPERATURE SETTING - WB = 67.00 F

99.0% DESIGN DAY TEMPERATURE--HEATING = 13.00 F
 97.5% DESIGN DAY TEMPERATURE--COOLING = 92.00 F

DESIGN HEATING LOAD = 30.00 KBTU/HR
 DESIGN COOLING LOAD = 22.00 KBTU/HR

COOLING SEASON SENSIBLE-TO-TOTAL COOLING LOAD RATIOS
 BY AMBIENT TEMPERATURE BINS --

AMBIENT TEMP (F)	52.0	57.0	62.0	67.0	72.0	77.0	82.0	87.0	92.0	97.0
102.0										
S/T RATIO	1.000	0.984	0.929	0.847	0.831	0.840	0.868	0.835	0.831	0.826
0.800										

1PERFORMANCE CALCULATIONS:

SAMPLE RUN OF A LENNOX TWO-SPEED WITH LOW-SPEED LOCKOUT IN HEATING

LENNOX(2-SPEED) HP14 LEGEND II SERIES--HP14-261/411V W CP12-41V/E12Q3
 167**2 RANCH, TECH HOUSE 3
 NOXVILLE, TN

0*** HEATING SEASON CALCULATIONS:

(STEP CAPACITY MODULATION ALTERNATING TWO CAPACITY LEVELS
 AT APPROPRIATE AMBIENTS)

MDPT	AVE	COP			CAP		% ON DEMAND	BACKUP	ENERGY	ENERGY		
TEMP	HRS	LOAD	S-S	F/D	F/D/C	S-S	F/D	TIME	RATE	I2R	IN	OUT
(F)		(KBTUH)							(KW)	(KWH)	(KWH)	(KBTU)
-13.	2.	36.01	1.01	1.01	1.01	8.21	8.21	100.	12.38	16.3	21.0	72.0
-8.	2.	39.11	1.15	1.15	1.15	9.85	9.85	100.	12.50	17.1	22.2	78.2
-3.	3.	27.20	1.30	1.30	1.30	11.63	11.63	100.	12.62	13.7	21.5	81.6

2.	12.	23.13	1.46	1.46	1.46	13.57	13.57	100.	12.72	33.6	66.2	277.6
7.	3.	25.06	1.63	1.63	1.63	15.65	15.65	100.	12.81	8.3	16.7	75.2
12.	7.	22.01	1.81	1.81	1.81	17.89	17.89	100.	12.89	8.5	28.7	154.1
17.	19.	22.62	1.99	1.99	1.99	20.20	20.33	100.	13.00	12.7	69.7	429.7
22.	33.	21.71	2.13	2.11	2.09	22.43	22.43	97.	3.12	0.0	100.3	716.3
27.	61.	17.60	2.26	2.23	2.09	24.79	25.40	74.	3.34	0.0	150.6	1073.7
32.	143.	15.31	2.42	2.33	2.12	27.52	28.38	59.	3.56	0.0	302.8	2189.8
37.	136.	11.83	2.56	2.46	2.15	30.30	31.66	43.	3.77	0.0	219.2	1608.5
42.	142.	7.47	2.66	2.66	2.25	32.67	32.67	27.	3.60	0.0	138.0	1060.2
47.	165.	4.23	3.00	3.00	2.47	22.12	22.12	23.	2.16	0.0	82.9	697.5
52.	163.	2.92	3.18	3.18	2.57	23.95	23.95	15.	2.20	0.0	54.4	476.7
57.	141.	1.54	3.36	3.36	2.66	25.80	25.80	8.	2.25	0.0	23.9	217.0
62.	63.	1.12	3.52	3.52	2.78	27.54	27.54	5.	2.29	0.0	7.5	70.8
67.	59.	0.49	3.70	3.70	2.90	29.46	29.46	2.	2.33	0.0	2.9	29.0
72.	28.	0.11	3.88	3.88	3.03	31.36	31.36	0.	2.37	0.0	0.3	3.1

*** HEATING SEASON PERFORMANCE SUMMARY:

SEASONAL ENERGY INPUT	1328.6 KWH	BACKUP I2R ENERGY	110.2 KWH
SEASONAL ENERGY OUTPUT	9310.9 KBTU	PARASITIC ENERGY	0.0 KWH
SEASONAL PERFORMANCE FACTOR	2.053	HOURS OF OPERATION	384.9 HRS
		I2R TEMPERING ENERGY	34.4 KWH
		DEFROST HP ENERGY	8.2 KWH
		TOTAL DEFROST TIME	3.4 HRS
		NUMBER OF DEFROSTS	34.6

*** SEASONAL ENERGY USE BREAKDOWN:

0-- DYNAMIC LOSS BREAKDOWN --

0FROSTING/DEFROSTING LOSSES -

DIRECT FROSTING/DEFROSTING ENERGY LOSS	20.6 KWH
INDIRECT CHANGE	
IN BACKUP HEAT REQUIREMENTS	-0.8 KWH
IN CYCLING LOSSES	4.6 KWH
IN PARASITICS	0.0 KWH

SEASONAL ENERGY LOSS DUE TO FROSTING/DEFROSTING 24.4 KWH

0CYCLING LOSSES -

DIRECT CYCLING ENERGY LOSS	114.4 KWH
INDIRECT CHANGE	
IN PARASITICS	0.0 KWH

SEASONAL ENERGY LOSS DUE TO CYCLING 114.4 KWH

0-- USE AND LOSS SUMMARY --

0STEADY-STATE ENERGY USE -

BASE TOTAL, EXCLUDING BACKUP HEAT AND PARASITICS	1078.9 KWH (81.2%)
BACKUP HEAT REQUIREMENTS	111.0 KWH (8.4%)
ON-TIME PARASITICS	0.0 KWH (0.0%)

OFF-TIME PARASITICS	0.0 KWH (0.0%)
ODYNAMIC LOSSES -	
FROSTING/DEFROSTING	24.4 KWH (1.8%)
CYCLING	114.4 KWH (8.6%)

TOTAL ENERGY USE FOR THE SEASON	1328.6 KWH (100.0%)

1PERFORMANCE CALCULATIONS:

SAMPLE RUN OF A LENNOX TWO-SPEED WITH LOW-SPEED LOCKOUT IN HEATING

LENNOX(2-SPEED) HP14 LEGEND II SERIES--HP14-261/411V W CP12-41V/E12Q3
167***2 RANCH, TECH HOUSE 3
NOXVILLE, TN

0*** COOLING SEASON CALCULATIONS:

(STEP CAPACITY MODULATION WITH ONLY ONE CAPACITY LEVEL
USED AT EACH AMBIENT)

MDPT	AVE	COP			CAP		% ON DEMAND	BACKUP	ENERGY	ENERGY		
TEMP	HRS	LOAD	S-S	F/D	F/D/C	S-S	F/D	TIME	RATE	I2R	IN	OUT
(F)		(KBTUH)							(KW)	(KWH)	(KWH)	(KBTU)
57.	35.	0.59	2.70	2.70	2.36	18.88	18.88	4.	2.05	0.0	2.5	20.5
62.	61.	1.95	2.62	2.62	2.32	18.72	18.72	12.	2.09	0.0	15.0	118.7
67.	222.	3.50	2.55	2.55	2.28	18.57	18.57	21.	2.13	0.0	99.7	776.9
72.	223.	5.87	2.49	2.49	2.26	18.41	18.41	35.	2.17	0.0	169.3	1308.9
77.	143.	8.50	2.42	2.42	2.25	18.26	18.26	50.	2.21	0.0	158.0	1216.1
82.	118.	9.66	2.36	2.36	2.22	18.10	18.10	57.	2.25	0.0	150.7	1140.3
87.	92.	11.89	2.29	2.29	2.19	17.95	17.95	69.	2.30	0.0	146.3	1093.9
92.	35.	12.85	2.21	2.21	2.13	17.79	17.79	75.	2.35	0.0	61.8	449.8
97.	1.	14.61	2.14	2.14	2.09	17.64	17.64	85.	2.42	0.0	2.0	14.6
102.	1.	15.03	2.07	2.07	2.03	17.49	17.49	88.	2.48	0.0	2.2	15.0

*** COOLING SEASON PERFORMANCE SUMMARY:

SEASONAL ENERGY INPUT	807.6 KWH	BACKUP I2R ENERGY	0.0 KWH
SEASONAL ENERGY OUTPUT	6154.7 KBTU	PARASITIC ENERGY	0.0 KWH
SEASONAL PERFORMANCE FACTOR	2.233	HOURS OF OPERATION	363.5 HRS

0*** SEASONAL ENERGY USE BREAKDOWN:

0-- DYNAMIC LOSS BREAKDOWN --

OCYCLING LOSSES -

 DIRECT CYCLING ENERGY LOSS 56.4 KWH

 INDIRECT CHANGE

 IN PARASITICS 0.0 KWH

SEASONAL ENERGY LOSS DUE TO CYCLING	56.4 KWH
0-- USE AND LOSS SUMMARY --	
OSTEADY-STATE ENERGY USE -	
BASE TOTAL, EXCLUDING BACKUP HEAT AND PARASITICS	751.1 KWH (93.0%)
BACKUP HEAT REQUIREMENTS	0.0 KWH (0.0%)
ON-TIME PARASITICS	0.0 KWH (0.0%)
OFF-TIME PARASITICS	0.0 KWH (0.0%)
ODYNAMIC LOSSES -	
FROSTING/DEFROSTING	0.0 KWH (0.0%)
CYCLING	56.4 KWH (7.0%)

TOTAL ENERGY USE FOR THE SEASON	807.6 KWH (100.0%)

1PERFORMANCE CALCULATIONS:

SAMPLE RUN OF A LENNOX TWO-SPEED WITH LOW-SPEED LOCKOUT IN HEATING

LENNOX(2-SPEED) HP14 LEGEND II SERIES--HP14-261/411V W CP12-41V/E12Q3
167**2 RANCH, TECH HOUSE 3
NOXVILLE, TN

*** ANNUAL PERFORMANCE SUMMARY:

ANNUAL ENERGY INPUT	2136.2 KWH	BACKUP I2R ENERGY	110.2 KWH
ANNUAL ENERGY OUTPUT	15465.6 KBTU	PARASITIC ENERGY	0.0 KWH
ANNUAL PERFORMANCE FACTOR	2.121	HOURS OF OPERATION	748.4 HRS
		I2R TEMPERING ENERGY	34.4 KWH
		DEFROST HP ENERGY	8.2 KWH
		TOTAL DEFROST TIME	3.4 HRS
		NUMBER OF DEFROSTS	34.6

0*** ANNUAL ENERGY USE BREAKDOWN:

0-- DYNAMIC LOSS BREAKDOWN --

OFROSTING/DEFROSTING LOSSES -

DIRECT FROSTING/DEFROSTING ENERGY LOSS	20.6 KWH
INDIRECT CHANGE	
IN BACKUP HEAT REQUIREMENTS	-0.8 KWH
IN CYCLING LOSSES	4.6 KWH
IN PARASITICS	0.0 KWH

ANNUAL ENERGY LOSS DUE TO FROSTING/DEFROSTING	24.4 KWH
OCYCLING LOSSES -	
DIRECT CYCLING ENERGY LOSS	170.8 KWH
INDIRECT CHANGE	

IN PARASITICS	0.0 KWH
-----	-----
ANNUAL ENERGY LOSS DUE TO CYCLING	170.8 KWH
0-- USE AND LOSS SUMMARY --	
OSTEADY-STATE ENERGY USE -	
BASE TOTAL, EXCLUDING BACKUP HEAT AND PARASITICS	1830.0 KWH (85.7%)
BACKUP HEAT REQUIREMENTS	111.0 KWH (5.2%)
ON-TIME PARASITICS	0.0 KWH (0.0%)
OFF-TIME PARASITICS	0.0 KWH (0.0%)
ODYNAMIC LOSSES -	
FROSTING/DEFROSTING	24.4 KWH (1.1%)
CYCLING	170.8 KWH (8.0%)
-----	-----
TOTAL ENERGY USE FOR THE YEAR	2136.2 KWH (100.0%)

1

B.13 Dual-Speed Mode HVAC/Loads Data File Results (SOT=42°F)

INPUT SUMMARY:

ELECTRIC-DRIVEN HEAT PUMP

SAMPLE RUN OF A LENNOX TWO-SPEED WITH LOW-SPEED LOCKOUT IN HEATING

***** SUMMARY OF HEATING PERFORMANCE DATA:

LENNOX(2-SPEED) HP14 LEGEND II SERIES--HP14-261/411V W CP12-41V/E12Q3
(STEP CAPACITY MODULATION ALTERNATING TWO CAPACITY LEVELS
AT APPROPRIATE AMBIENTS)

----- HEATING MODE DATA FOR -----
----- MODULATION RATIO OF 0.50 -----

*** STEADY-STATE DATA:

PT	AMBIENT TEMPERATURE (F)	STEADY-STATE POWER (KWH)	PT	AMBIENT TEMPERATURE (F)	STEADY-STATE CAPACITY (KBTUH)
1	-15.00	.010	1	-15.00	0.00
2	5.00	.010	2	5.00	0.00
3	15.00	.010	3	15.00	0.00
4	25.00	1.140	4	25.00	14.12
5	35.00	1.220	5	35.00	17.76
6	45.00	1.310	6	45.00	21.40
7	50.00	1.350	7	50.00	23.20
8	55.00	1.400	8	55.00	25.10
9	60.00	1.440	9	60.00	26.80
10	65.00	1.480	10	65.00	28.70

*** CYCLING LOSS DATA:

CD = 0.220

*** FROST/DEFROST DATA:

ORNL TUBE & PLATE FIN, FROSTING/RECOVERY DATA USED

FROST INITIATION POINT = 37.00 DEG F
DEFROST TEMPERING HEAT = 10.00 KW

DEFROST COOLING CAPACITY GIVEN BY ORNL WAVY FIN DATA
DEFROST COOLING COP GIVEN BY ORNL WAVY FIN DATA

DEFROST LENGTH AND
TIME BETWEEN DEFROSTS GIVEN BY ORNL WAVY FIN DATA

*** ON-TIME PARASITIC DATA:

ON-TIME PARASITIC POWER IS 835.00 WATTS TIMES THE FRACTIONAL ON TIME.
AMOUNT OF ON-TIME PARASITICS ADDED TO S-S CAPACITY VALUES IS 0.00 WATTS

AMOUNT OF ON-TIME PARASITICS ADDED TO S-S COP VALUES IS 835.00 WATTS

----- HEATING MODE DATA FOR -----

----- MODULATION RATIO OF 1.00 -----

*** STEADY-STATE DATA:

AMBIENT			STEADY-STATE		
PT	TEMPERATURE		POWER	PT	TEMPERATURE
	(F)		(KWH)		(F)
1	-15.00		1.490	1	-15.00
2	5.00		1.940	2	5.00
3	15.00		2.100	3	15.00
4	25.00		2.330	4	25.00
5	35.00		2.580	5	35.00
6	45.00		2.840	6	45.00
7	50.00		2.980	7	50.00
8	55.00		3.130	8	55.00
9	60.00		3.260	9	60.00
10	65.00		3.400	10	65.00

AMBIENT			STEADY-STATE		
PT	TEMPERATURE		CAPACITY	PT	TEMPERATURE
	(F)		(KBTUH)		(F)
1	-15.00		7.60	1	-15.00
2	5.00		14.80	2	5.00
3	15.00		19.30	3	15.00
4	25.00		23.77	4	25.00
5	35.00		29.29	5	35.00
6	45.00		34.00	6	45.00
7	50.00		36.70	7	50.00
8	55.00		39.46	8	55.00
9	60.00		42.09	9	60.00
10	65.00		44.60	10	65.00

*** CYCLING LOSS DATA:

CD = 0.200

*** FROST/DEFROST DATA:

ORNL TUBE & PLATE FIN, FROSTING/RECOVERY DATA USED

FROST INITIATION POINT = 42.00 DEG F

DEFROST TEMPERING HEAT = 10.00 KW

DEFROST COOLING CAPACITY GIVEN BY ORNL WAVY FIN DATA

DEFROST COOLING COP GIVEN BY ORNL WAVY FIN DATA

DEFROST LENGTH AND

TIME BETWEEN DEFROSTS GIVEN BY ORNL WAVY FIN DATA

*** ON-TIME PARASITIC DATA:

ON-TIME PARASITIC POWER IS 835.00 WATTS TIMES THE FRACTIONAL ON TIME.

AMOUNT OF ON-TIME PARASITICS ADDED TO S-S CAPACITY VALUES IS 0.00 WATTS

AMOUNT OF ON-TIME PARASITICS ADDED TO S-S COP VALUES IS 835.00 WATTS

***** SUMMARY OF COOLING PERFORMANCE DATA:

LENNOX(2-SPEED) HP14 LEGEND II SERIES--HP14-261/411V W CP12-41V/E12Q3
(STEP CAPACITY MODULATION ALTERNATING TWO CAPACITY LEVELS
AT APPROPRIATE AMBIENTS)

----- COOLING MODE DATA FOR -----

----- MODULATION RATIO OF 0.50 -----

*** STEADY-STATE DATA:

AMBIENT			STEADY-STATE		
PT	TEMPERATURE	POWER	PT	TEMPERATURE	CAPACITY
	(F)	(KWH)		(F)	(KBTUH)
1	75.00	1.360	1	75.00	18.32
2	85.00	1.440	2	85.00	18.01
3	95.00	1.560	3	95.00	17.70
4	105.00	1.680	4	105.00	17.40

*** CYCLING LOSS DATA:

CD = 0.130

*** ON-TIME PARASITIC DATA:

ON-TIME PARASITIC POWER IS 835.00 WATTS TIMES THE FRACTIONAL ON TIME.
 AMOUNT OF ON-TIME PARASITICS ADDED TO S-S CAPACITY VALUES IS 0.00 WATTS
 AMOUNT OF ON-TIME PARASITICS ADDED TO S-S COP VALUES IS 835.00 WATTS

----- COOLING MODE DATA FOR -----
 ----- MODULATION RATIO OF 1.00 -----

*** STEADY-STATE DATA:

AMBIENT		STEADY-STATE	AMBIENT		STEADY-STATE
PT	TEMPERATURE	POWER	PT	TEMPERATURE	CAPACITY
	(F)	(KWH)		(F)	(KBTUH)
1	75.00	3.170	1	75.00	28.53
2	85.00	3.340	2	85.00	27.52
3	95.00	3.500	3	95.00	26.50
4	105.00	3.660	4	105.00	25.49

*** CYCLING LOSS DATA:

CD = 0.130

*** ON-TIME PARASITIC DATA:

ON-TIME PARASITIC POWER IS 835.00 WATTS TIMES THE FRACTIONAL ON TIME.
 AMOUNT OF ON-TIME PARASITICS ADDED TO S-S CAPACITY VALUES IS 0.00 WATTS
 AMOUNT OF ON-TIME PARASITICS ADDED TO S-S COP VALUES IS 835.00 WATTS

***** MODE AND MODULATION INDEPENDENT HEAT PUMP DATA:

*** OFF-TIME PARASITIC DATA:

OFF-TIME PARASITIC POWER IS 0.00 WATTS TIMES THE FRACTIONAL OFF TIME.

*** UNIT SIZE SCALING:

THE INPUT CAPACITY, POWER, AND PARASITIC VALUES WERE NOT SCALED

***** HOUSE, WEATHER, AND LOADS INFORMATION:

167**2 RANCH, TECH HOUSE 3
THE HOUSE HAS 1800. SQUARE FEET OF FLAT ROOF AREA WITH
R-38. CEILING AND
R-19. WALLS

WEATHER FOR NOXVILLE, TN

WINTER INDOOR TEMPERATURE SETTING - DB = 70.00 F
SUMMER INDOOR TEMPERATURE SETTING - DB = 78.00 F
SUMMER INDOOR TEMPERATURE SETTING - WB = 67.00 F

99.0% DESIGN DAY TEMPERATURE--HEATING = 13.00 F
97.5% DESIGN DAY TEMPERATURE--COOLING = 92.00 F

DESIGN HEATING LOAD = 30.00 KBTU/HR
DESIGN COOLING LOAD = 22.00 KBTU/HR

COOLING SEASON SENSIBLE-TO-TOTAL COOLING LOAD RATIOS
BY AMBIENT TEMPERATURE BINS --

AMBIENT TEMP (F)	52.0	57.0	62.0	67.0	72.0	77.0	82.0	87.0	92.0	97.0
102.0										
S/T RATIO	1.000	0.984	0.929	0.847	0.831	0.840	0.868	0.835	0.831	0.826
0.800										

1PERFORMANCE CALCULATIONS:

SAMPLE RUN OF A LENNOX TWO-SPEED WITH LOW-SPEED LOCKOUT IN HEATING

LENNOX(2-SPEED) HP14 LEGEND II SERIES--HP14-261/411V W CP12-41V/E12Q3
167**2 RANCH, TECH HOUSE 3
NOXVILLE, TN

0*** HEATING SEASON CALCULATIONS:

(STEP CAPACITY MODULATION ALTERNATING TWO CAPACITY LEVELS
AT APPROPRIATE AMBIENTS)

MDPT		AVE	COP			CAP		% ON	DEMAND	BACKUP	ENERGY	ENERGY
TEMP	HRS	LOAD	S-S	F/D	F/D/C	S-S	F/D	TIME	RATE	I2R	IN	OUT
(F)		(KBTUH)							(KW)	(KWH)	(KWH)	(KBTU)
-13.	2.	36.01	1.01	1.01	1.01	8.21	8.21	100.	12.38	16.3	21.0	72.0
-8.	2.	39.11	1.15	1.15	1.15	9.85	9.85	100.	12.50	17.1	22.2	78.2
-3.	3.	27.20	1.30	1.30	1.30	11.63	11.63	100.	12.62	13.7	21.5	81.6
2.	12.	23.13	1.46	1.46	1.46	13.57	13.57	100.	12.72	33.6	66.2	277.6
7.	3.	25.06	1.63	1.63	1.63	15.65	15.65	100.	12.81	8.3	16.7	75.2
12.	7.	22.01	1.81	1.81	1.81	17.89	17.89	100.	12.89	8.5	28.7	154.1
17.	19.	22.62	1.99	1.99	1.99	20.20	20.33	100.	13.00	12.7	69.7	429.7
22.	33.	21.71	2.13	2.11	2.09	22.43	22.43	97.	3.12	0.0	100.3	716.3
27.	61.	17.60	2.26	2.23	2.09	24.79	25.40	74.	3.34	0.0	150.6	1073.7
32.	143.	15.31	2.42	2.33	2.12	27.52	28.38	59.	3.56	0.0	302.8	2189.8
37.	136.	11.83	2.56	2.46	2.15	30.30	31.66	43.	3.77	0.0	219.2	1608.5
42.	142.	7.47	2.81	2.81	2.42	20.31	20.31	43.	2.12	0.0	128.4	1060.2
47.	165.	4.23	3.00	3.00	2.47	22.12	22.12	23.	2.16	0.0	82.9	697.5
52.	163.	2.92	3.18	3.18	2.57	23.95	23.95	15.	2.20	0.0	54.4	476.7
57.	141.	1.54	3.36	3.36	2.66	25.80	25.80	8.	2.25	0.0	23.9	217.0
62.	63.	1.12	3.52	3.52	2.78	27.54	27.54	5.	2.29	0.0	7.5	70.8
67.	59.	0.49	3.70	3.70	2.90	29.46	29.46	2.	2.33	0.0	2.9	29.0
72.	28.	0.11	3.88	3.88	3.03	31.36	31.36	0.	2.37	0.0	0.3	3.1

*** HEATING SEASON PERFORMANCE SUMMARY:

SEASONAL ENERGY INPUT	1319.0 KWH	BACKUP I2R ENERGY	110.2 KWH
SEASONAL ENERGY OUTPUT	9310.9 KBTU	PARASITIC ENERGY	0.0 KWH
SEASONAL PERFORMANCE FACTOR	2.068	HOURS OF OPERATION	407.1 HRS
		I2R TEMPERING ENERGY	34.4 KWH
		DEFROST HP ENERGY	8.2 KWH
		TOTAL DEFROST TIME	3.4 HRS
		NUMBER OF DEFROSTS	34.6

0*** SEASONAL ENERGY USE BREAKDOWN:

0-- DYNAMIC LOSS BREAKDOWN --

0FROSTING/DEFROSTING LOSSES -

DIRECT FROSTING/DEFROSTING ENERGY LOSS	20.6 KWH
INDIRECT CHANGE	
IN BACKUP HEAT REQUIREMENTS	-0.8 KWH
IN CYCLING LOSSES	4.6 KWH
IN PARASITICS	0.0 KWH

SEASONAL ENERGY LOSS DUE TO FROSTING/DEFROSTING	24.4 KWH
0CYCLING LOSSES -	
DIRECT CYCLING ENERGY LOSS	110.9 KWH
INDIRECT CHANGE	

IN PARASITICS	0.0 KWH

SEASONAL ENERGY LOSS DUE TO CYCLING	110.9 KWH
0-- USE AND LOSS SUMMARY --	
OSTEADY-STATE ENERGY USE -	
BASE TOTAL, EXCLUDING BACKUP HEAT AND PARASITICS	1072.7 KWH (81.3%)
BACKUP HEAT REQUIREMENTS	111.0 KWH (8.4%)
ON-TIME PARASITICS	0.0 KWH (0.0%)
OFF-TIME PARASITICS	0.0 KWH (0.0%)
ODYNAMIC LOSSES -	
FROSTING/DEFROSTING	24.4 KWH (1.9%)
CYCLING	110.9 KWH (8.4%)

TOTAL ENERGY USE FOR THE SEASON	1319.0 KWH (100.0%)

1PERFORMANCE CALCULATIONS:

SAMPLE RUN OF A LENNOX TWO-SPEED WITH LOW-SPEED LOCKOUT IN HEATING

LENNOX(2-SPEED) HP14 LEGEND II SERIES--HP14-261/411V W CP12-41V/E12Q3
167**2 RANCH, TECH HOUSE 3
NOXVILLE, TN

0*** COOLING SEASON CALCULATIONS:

(STEP CAPACITY MODULATION WITH ONLY ONE CAPACITY LEVEL
USED AT EACH AMBIENT)

MDPT	AVE	COP		CAP		% ON DEMAND		BACKUP	ENERGY	ENERGY		
TEMP	HRS	LOAD	S-S	F/D	F/D/C	S-S	F/D	TIME	RATE	I2R	IN	OUT
(F)		(KBTUH)							(KW)	(KWH)	(KWH)	(KBTU)
57.	35.	0.59	2.70	2.70	2.36	18.88	18.88	4.	2.05	0.0	2.5	20.5
62.	61.	1.95	2.62	2.62	2.32	18.72	18.72	12.	2.09	0.0	15.0	118.7
67.	222.	3.50	2.55	2.55	2.28	18.57	18.57	21.	2.13	0.0	99.7	776.9
72.	223.	5.87	2.49	2.49	2.26	18.41	18.41	35.	2.17	0.0	169.3	1308.9
77.	143.	8.50	2.42	2.42	2.25	18.26	18.26	50.	2.21	0.0	158.0	1216.1
82.	118.	9.66	2.36	2.36	2.22	18.10	18.10	57.	2.25	0.0	150.7	1140.3
87.	92.	11.89	2.29	2.29	2.19	17.95	17.95	69.	2.30	0.0	146.3	1093.9
92.	35.	12.85	2.21	2.21	2.13	17.79	17.79	75.	2.35	0.0	61.8	449.8
97.	1.	14.61	2.14	2.14	2.09	17.64	17.64	85.	2.42	0.0	2.0	14.6
102.	1.	15.03	2.07	2.07	2.03	17.49	17.49	88.	2.48	0.0	2.2	15.0

*** COOLING SEASON PERFORMANCE SUMMARY:

0SEASONAL ENERGY INPUT	807.6 KWH	BACKUP I2R ENERGY	0.0 KWH
SEASONAL ENERGY OUTPUT	6154.7 KBTU	PARASITIC ENERGY	0.0 KWH
SEASONAL PERFORMANCE FACTOR	2.233	HOURS OF OPERATION	363.5 HRS

0*** SEASONAL ENERGY USE BREAKDOWN:

0-- DYNAMIC LOSS BREAKDOWN --

0CYCLING LOSSES -

DIRECT CYCLING ENERGY LOSS	56.4 KWH
INDIRECT CHANGE	
IN PARASITICS	0.0 KWH

SEASONAL ENERGY LOSS DUE TO CYCLING	56.4 KWH
-------------------------------------	----------

0-- USE AND LOSS SUMMARY --

0STEADY-STATE ENERGY USE -

BASE TOTAL, EXCLUDING BACKUP HEAT AND PARASITICS	751.1 KWH (93.0%)
BACKUP HEAT REQUIREMENTS	0.0 KWH (0.0%)
ON-TIME PARASITICS	0.0 KWH (0.0%)
OFF-TIME PARASITICS	0.0 KWH (0.0%)

0DYNAMIC LOSSES -

FROSTING/DEFROSTING	0.0 KWH (0.0%)
CYCLING	56.4 KWH (7.0%)

TOTAL ENERGY USE FOR THE SEASON	807.6 KWH (100.0%)
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1PERFORMANCE CALCULATIONS:

SAMPLE RUN OF A LENNOX TWO-SPEED WITH LOW-SPEED LOCKOUT IN HEATING

LENNOX(2-SPEED) HP14 LEGEND II SERIES--HP14-261/411V W CP12-41V/E12Q3
167**2 RANCH, TECH HOUSE 3
NOXVILLE, TN

*** ANNUAL PERFORMANCE SUMMARY:

0ANNUAL ENERGY INPUT	2126.6 KWH	BACKUP I2R ENERGY	110.2 KWH
ANNUAL ENERGY OUTPUT	15465.6 KBTU	PARASITIC ENERGY	0.0 KWH
ANNUAL PERFORMANCE FACTOR	2.131	HOURS OF OPERATION	770.7 HRS
		I2R TEMPERING ENERGY	34.4 KWH
		DEFROST HP ENERGY	8.2 KWH
		TOTAL DEFROST TIME	3.4 HRS
		NUMBER OF DEFROSTS	34.6

0*** ANNUAL ENERGY USE BREAKDOWN:

0-- DYNAMIC LOSS BREAKDOWN --

0FROSTING/DEFROSTING LOSSES -

DIRECT FROSTING/DEFROSTING ENERGY LOSS	20.6 KWH
INDIRECT CHANGE	
IN BACKUP HEAT REQUIREMENTS	-0.8 KWH
IN CYCLING LOSSES	4.6 KWH

IN PARASITICS	0.0 KWH
-----	-----
ANNUAL ENERGY LOSS DUE TO FROSTING/DEFROSTING	24.4 KWH
OCYCLING LOSSES -	
DIRECT CYCLING ENERGY LOSS	167.4 KWH
INDIRECT CHANGE	
IN PARASITICS	0.0 KWH
-----	-----
ANNUAL ENERGY LOSS DUE TO CYCLING	167.4 KWH
0-- USE AND LOSS SUMMARY --	
OSTEADY-STATE ENERGY USE -	
BASE TOTAL, EXCLUDING BACKUP HEAT AND PARASITICS	1823.9 KWH (85.8%)
BACKUP HEAT REQUIREMENTS	111.0 KWH (5.2%)
ON-TIME PARASITICS	0.0 KWH (0.0%)
OFF-TIME PARASITICS	0.0 KWH (0.0%)
ODYNAMIC LOSSES -	
FROSTING/DEFROSTING	24.4 KWH (1.1%)
CYCLING	167.4 KWH (7.9%)
-----	-----
TOTAL ENERGY USE FOR THE YEAR	2126.6 KWH (100.0%)

B.14 Dual-Speed Mode HVAC/Loads Data File Results (SOT=37°F)

INPUT SUMMARY:

ELECTRIC-DRIVEN HEAT PUMP

SAMPLE RUN OF A LENNOX TWO-SPEED WITH LOW-SPEED LOCKOUT IN HEATING

***** SUMMARY OF HEATING PERFORMANCE DATA:

LENNOX(2-SPEED) HP14 LEGEND II SERIES--HP14-261/411V W CP12-41V/E12Q3
(STEP CAPACITY MODULATION ALTERNATING TWO CAPACITY LEVELS
AT APPROPRIATE AMBIENTS)

----- HEATING MODE DATA FOR -----
----- MODULATION RATIO OF 0.50 -----

*** STEADY-STATE DATA:

PT	AMBIENT TEMPERATURE (F)	STEADY-STATE POWER (KWH)	PT	AMBIENT TEMPERATURE (F)	STEADY-STATE CAPACITY (KBTUH)
1	-15.00	.010	1	-15.00	0.00
2	5.00	.010	2	5.00	0.00
3	15.00	.010	3	15.00	0.00
4	25.00	1.140	4	25.00	14.12
5	35.00	1.220	5	35.00	17.76
6	45.00	1.310	6	45.00	21.40
7	50.00	1.350	7	50.00	23.20
8	55.00	1.400	8	55.00	25.10
9	60.00	1.440	9	60.00	26.80
10	65.00	1.480	10	65.00	28.70

*** CYCLING LOSS DATA:

CD = 0.220

*** FROST/DEFROST DATA:

ORNL TUBE & PLATE FIN, FROSTING/RECOVERY DATA USED

FROST INITIATION POINT = 37.00 DEG F

DEFROST TEMPERING HEAT = 10.00 KW

DEFROST COOLING CAPACITY GIVEN BY ORNL WAVY FIN DATA
DEFROST COOLING COP GIVEN BY ORNL WAVY FIN DATA

DEFROST LENGTH AND
TIME BETWEEN DEFROSTS GIVEN BY ORNL WAVY FIN DATA

*** ON-TIME PARASITIC DATA:

ON-TIME PARASITIC POWER IS 835.00 WATTS TIMES THE FRACTIONAL ON TIME.
AMOUNT OF ON-TIME PARASITICS ADDED TO S-S CAPACITY VALUES IS 0.00 WATTS
AMOUNT OF ON-TIME PARASITICS ADDED TO S-S COP VALUES IS 835.00 WATTS

----- HEATING MODE DATA FOR -----
----- MODULATION RATIO OF 1.00 -----

*** STEADY-STATE DATA:

PT	AMBIENT TEMPERATURE (F)	STEADY-STATE POWER (KWH)	PT	AMBIENT TEMPERATURE (F)	STEADY-STATE CAPACITY (KBTUH)
1	-15.00	1.490	1	-15.00	7.60
2	5.00	1.940	2	5.00	14.80
3	15.00	2.100	3	15.00	19.30
4	25.00	2.330	4	25.00	23.77
5	35.00	2.580	5	35.00	29.29
6	45.00	2.840	6	45.00	34.00
7	50.00	2.980	7	50.00	36.70
8	55.00	3.130	8	55.00	39.46
9	60.00	3.260	9	60.00	42.09
10	65.00	3.400	10	65.00	44.60

*** CYCLING LOSS DATA:

CD = 0.200

*** FROST/DEFROST DATA:

ORNL TUBE & PLATE FIN, FROSTING/RECOVERY DATA USED

FROST INITIATION POINT = 42.00 DEG F
DEFROST TEMPERING HEAT = 10.00 KW

DEFROST COOLING CAPACITY GIVEN BY ORNL WAVY FIN DATA
DEFROST COOLING COP GIVEN BY ORNL WAVY FIN DATA
DEFROST LENGTH AND

TIME BETWEEN DEFROSTS GIVEN BY ORNL WAVY FIN DATA

*** ON-TIME PARASITIC DATA:

ON-TIME PARASITIC POWER IS 835.00 WATTS TIMES THE FRACTIONAL ON TIME.
AMOUNT OF ON-TIME PARASITICS ADDED TO S-S CAPACITY VALUES IS 0.00 WATTS
AMOUNT OF ON-TIME PARASITICS ADDED TO S-S COP VALUES IS 835.00 WATTS

***** SUMMARY OF COOLING PERFORMANCE DATA:

LENNOX(2-SPEED) HP14 LEGEND II SERIES--HP14-261/411V W CP12-41V/E12Q3
(STEP CAPACITY MODULATION ALTERNATING TWO CAPACITY LEVELS
AT APPROPRIATE AMBIENTS)

----- COOLING MODE DATA FOR -----
----- MODULATION RATIO OF 0.50 -----

*** STEADY-STATE DATA:

AMBIENT			STEADY-STATE		
PT	TEMPERATURE	POWER	PT	TEMPERATURE	CAPACITY
	(F)	(KWH)		(F)	(KBTUH)
1	75.00	1.360	1	75.00	18.32
2	85.00	1.440	2	85.00	18.01
3	95.00	1.560	3	95.00	17.70
4	105.00	1.680	4	105.00	17.40

*** CYCLING LOSS DATA:

CD = 0.130

*** ON-TIME PARASITIC DATA:

ON-TIME PARASITIC POWER IS 835.00 WATTS TIMES THE FRACTIONAL ON TIME.
AMOUNT OF ON-TIME PARASITICS ADDED TO S-S CAPACITY VALUES IS 0.00 WATTS
AMOUNT OF ON-TIME PARASITICS ADDED TO S-S COP VALUES IS 835.00 WATTS

----- COOLING MODE DATA FOR -----
----- MODULATION RATIO OF 1.00 -----

*** STEADY-STATE DATA:

PT	AMBIENT	STEADY-STATE	PT	AMBIENT	STEADY-STATE
	TEMPERATURE (F)	POWER (KWH)		TEMPERATURE (F)	CAPACITY (KBTUH)
1	75.00	3.170	1	75.00	28.53
2	85.00	3.340	2	85.00	27.52
3	95.00	3.500	3	95.00	26.50
4	105.00	3.660	4	105.00	25.49

*** CYCLING LOSS DATA:

CD = 0.130

*** ON-TIME PARASITIC DATA:

ON-TIME PARASITIC POWER IS 835.00 WATTS TIMES THE FRACTIONAL ON TIME.
 AMOUNT OF ON-TIME PARASITICS ADDED TO S-S CAPACITY VALUES IS 0.00 WATTS
 AMOUNT OF ON-TIME PARASITICS ADDED TO S-S COP VALUES IS 835.00 WATTS

***** MODE AND MODULATION INDEPENDENT HEAT PUMP DATA:

*** OFF-TIME PARASITIC DATA:

OFF-TIME PARASITIC POWER IS 0.00 WATTS TIMES THE FRACTIONAL OFF TIME.

*** UNIT SIZE SCALING:

THE INPUT CAPACITY, POWER, AND PARASITIC VALUES WERE NOT SCALED

***** HOUSE, WEATHER, AND LOADS INFORMATION:

167**2 RANCH, TECH HOUSE 3
 THE HOUSE HAS 1800. SQUARE FEET OF FLAT ROOF AREA WITH
 R-38. CEILING AND

R-19. WALLS

WEATHER FOR NOXVILLE, TN

WINTER INDOOR TEMPERATURE SETTING - DB = 70.00 F
 SUMMER INDOOR TEMPERATURE SETTING - DB = 78.00 F
 SUMMER INDOOR TEMPERATURE SETTING - WB = 67.00 F

99.0% DESIGN DAY TEMPERATURE--HEATING = 13.00 F
 97.5% DESIGN DAY TEMPERATURE--COOLING = 92.00 F

DESIGN HEATING LOAD = 30.00 KBTU/HR
 DESIGN COOLING LOAD = 22.00 KBTU/HR

COOLING SEASON SENSIBLE-TO-TOTAL COOLING LOAD RATIOS
 BY AMBIENT TEMPERATURE BINS --

AMBIENT TEMP (F)	52.0	57.0	62.0	67.0	72.0	77.0	82.0	87.0	92.0	97.0
102.0										
S/T RATIO	1.000	0.984	0.929	0.847	0.831	0.840	0.868	0.835	0.831	0.826
0.800										

1PERFORMANCE CALCULATIONS:

SAMPLE RUN OF A LENNOX TWO-SPEED WITH LOW-SPEED LOCKOUT IN HEATING

LENNOX(2-SPEED) HP14 LEGEND II SERIES--HP14-261/411V W CP12-41V/E12Q3
 167**2 RANCH, TECH HOUSE 3
 NOXVILLE, TN

0*** HEATING SEASON CALCULATIONS:

(STEP CAPACITY MODULATION ALTERNATING TWO CAPACITY LEVELS
 AT APPROPRIATE AMBIENTS)

MDPT	AVE	COP			CAP		% ON DEMAND		BACKUP	ENERGY	ENERGY	
TEMP	HRS	LOAD	S-S	F/D	F/D/C	S-S	F/D	TIME	RATE	I2R	IN	OUT
(F)		(KBTUH)							(KW)	(KWH)	(KWH)	(KBTU)
-13.	2.	36.01	1.01	1.01	1.01	8.21	8.21	100.	12.38	16.3	21.0	72.0
-8.	2.	39.11	1.15	1.15	1.15	9.85	9.85	100.	12.50	17.1	22.2	78.2
-3.	3.	27.20	1.30	1.30	1.30	11.63	11.63	100.	12.62	13.7	21.5	81.6
	2.	12.23	1.46	1.46	1.46	13.57	13.57	100.	12.72	33.6	66.2	277.6
	7.	3.25	1.63	1.63	1.63	15.65	15.65	100.	12.81	8.3	16.7	75.2
	12.	7.22	1.81	1.81	1.81	17.89	17.89	100.	12.89	8.5	28.7	154.1
	17.	19.22	1.99	1.99	1.99	20.20	20.33	100.	13.00	12.7	69.7	429.7
	22.	33.21	2.13	2.11	2.09	22.43	22.43	97.	3.12	0.0	100.3	716.3
	27.	61.17	2.26	2.23	2.09	24.79	25.40	74.	3.34	0.0	150.6	1073.7

32.	143.	15.31	2.42	2.33	2.12	27.52	28.38	59.	3.56	0.0	302.8	2189.8
37.	136.	11.83	2.61	2.61	2.41	18.49	18.49	69.	2.07	0.0	195.8	1608.5
42.	142.	7.47	2.81	2.81	2.42	20.31	20.31	43.	2.12	0.0	128.4	1060.2
47.	165.	4.23	3.00	3.00	2.47	22.12	22.12	23.	2.16	0.0	82.9	697.5
52.	163.	2.92	3.18	3.18	2.57	23.95	23.95	15.	2.20	0.0	54.4	476.7
57.	141.	1.54	3.36	3.36	2.66	25.80	25.80	8.	2.25	0.0	23.9	217.0
62.	63.	1.12	3.52	3.52	2.78	27.54	27.54	5.	2.29	0.0	7.5	70.8
67.	59.	0.49	3.70	3.70	2.90	29.46	29.46	2.	2.33	0.0	2.9	29.0
72.	28.	0.11	3.88	3.88	3.03	31.36	31.36	0.	2.37	0.0	0.3	3.1

*** HEATING SEASON PERFORMANCE SUMMARY:

SEASONAL ENERGY INPUT	1295.7 KWH	BACKUP I2R ENERGY	110.2 KWH
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SEASONAL ENERGY OUTPUT	9310.9 KBTU	PARASITIC ENERGY	0.0 KWH
SEASONAL PERFORMANCE FACTOR	2.106	HOURS OF OPERATION	443.6 HRS

I2R TEMPERING ENERGY	20.7 KWH
DEFROST HP ENERGY	4.9 KWH
TOTAL DEFROST TIME	2.1 HRS
NUMBER OF DEFROSTS	22.3

*** SEASONAL ENERGY USE BREAKDOWN:

0-- DYNAMIC LOSS BREAKDOWN --

OFROSTING/DEFROSTING LOSSES -

DIRECT FROSTING/DEFROSTING ENERGY LOSS	12.9 KWH
INDIRECT CHANGE	
IN BACKUP HEAT REQUIREMENTS	-0.8 KWH
IN CYCLING LOSSES	2.7 KWH
IN PARASITICS	0.0 KWH

SEASONAL ENERGY LOSS DUE TO FROSTING/DEFROSTING	14.8 KWH
---	----------

OCYCLING LOSSES -

DIRECT CYCLING ENERGY LOSS	100.9 KWH
INDIRECT CHANGE	
IN PARASITICS	0.0 KWH

SEASONAL ENERGY LOSS DUE TO CYCLING	100.9 KWH
-------------------------------------	-----------

0-- USE AND LOSS SUMMARY --

OSTEADY-STATE ENERGY USE -

BASE TOTAL, EXCLUDING BACKUP HEAT AND PARASITICS	1069.0 KWH (82.5%)
BACKUP HEAT REQUIREMENTS	111.0 KWH (8.6%)
ON-TIME PARASITICS	0.0 KWH (0.0%)
OFF-TIME PARASITICS	0.0 KWH (0.0%)

ODYNAMIC LOSSES -

FROSTING/DEFROSTING	14.8 KWH (1.1%)
CYCLING	100.9 KWH (7.8%)

TOTAL ENERGY USE FOR THE SEASON

1295.7 KWH (100.0%)

1PERFORMANCE CALCULATIONS:

SAMPLE RUN OF A LENNOX TWO-SPEED WITH LOW-SPEED LOCKOUT IN HEATING

LENNOX(2-SPEED) HP14 LEGEND II SERIES--HP14-261/411V W CP12-41V/E12Q3

167**2 RANCH, TECH HOUSE 3

KNOXVILLE, TN

0*** COOLING SEASON CALCULATIONS:

(STEP CAPACITY MODULATION WITH ONLY ONE CAPACITY LEVEL
USED AT EACH AMBIENT)

MDPT	AVE	COP				CAP		% ON DEMAND	BACKUP	ENERGY	ENERGY	
TEMP	HRS	LOAD	S-S	F/D	F/D/C	S-S	F/D	TIME	RATE	I2R	IN	OUT
(F)		(KBTUH)							(KW)	(KWH)	(KWH)	(KBTU)
57.	35.	0.59	2.70	2.70	2.36	18.88	18.88	4.	2.05	0.0	2.5	20.5
62.	61.	1.95	2.62	2.62	2.32	18.72	18.72	12.	2.09	0.0	15.0	118.7
67.	222.	3.50	2.55	2.55	2.28	18.57	18.57	21.	2.13	0.0	99.7	776.9
72.	223.	5.87	2.49	2.49	2.26	18.41	18.41	35.	2.17	0.0	169.3	1308.9
77.	143.	8.50	2.42	2.42	2.25	18.26	18.26	50.	2.21	0.0	158.0	1216.1
82.	118.	9.66	2.36	2.36	2.22	18.10	18.10	57.	2.25	0.0	150.7	1140.3
87.	92.	11.89	2.29	2.29	2.19	17.95	17.95	69.	2.30	0.0	146.3	1093.9
92.	35.	12.85	2.21	2.21	2.13	17.79	17.79	75.	2.35	0.0	61.8	449.8
97.	1.	14.61	2.14	2.14	2.09	17.64	17.64	85.	2.42	0.0	2.0	14.6
102.	1.	15.03	2.07	2.07	2.03	17.49	17.49	88.	2.48	0.0	2.2	15.0

*** COOLING SEASON PERFORMANCE SUMMARY:

0SEASONAL ENERGY INPUT	807.6 KWH	BACKUP I2R ENERGY	0.0 KWH
SEASONAL ENERGY OUTPUT	6154.7 KBTU	PARASITIC ENERGY	0.0 KWH
SEASONAL PERFORMANCE FACTOR	2.233	HOURS OF OPERATION	363.5 HRS

0*** SEASONAL ENERGY USE BREAKDOWN:

0-- DYNAMIC LOSS BREAKDOWN --

0CYCLING LOSSES -

DIRECT CYCLING ENERGY LOSS 56.4 KWH

INDIRECT CHANGE

IN PARASITICS 0.0 KWH

SEASONAL ENERGY LOSS DUE TO CYCLING

56.4 KWH

0-- USE AND LOSS SUMMARY --

0STEADY-STATE ENERGY USE -

BASE TOTAL, EXCLUDING BACKUP HEAT AND PARASITICS 751.1 KWH (93.0%)

BACKUP HEAT REQUIREMENTS 0.0 KWH (0.0%)

ON-TIME PARASITICS 0.0 KWH (0.0%)

OFF-TIME PARASITICS	0.0 KWH (0.0%)
ODYNAMIC LOSSES -	
FROSTING/DEFROSTING	0.0 KWH (0.0%)
CYCLING	56.4 KWH (7.0%)

TOTAL ENERGY USE FOR THE SEASON	807.6 KWH (100.0%)

1PERFORMANCE CALCULATIONS:

SAMPLE RUN OF A LENNOX TWO-SPEED WITH LOW-SPEED LOCKOUT IN HEATING

LENNOX(2-SPEED) HP14 LEGEND II SERIES--HP14-261/411V W CP12-41V/E12Q3
167***2 RANCH, TECH HOUSE 3
NOXVILLE, TN

*** ANNUAL PERFORMANCE SUMMARY:

ANNUAL ENERGY INPUT	2103.2 KWH	BACKUP I2R ENERGY	110.2 KWH
ANNUAL ENERGY OUTPUT	15465.6 KBTU	PARASITIC ENERGY	0.0 KWH
ANNUAL PERFORMANCE FACTOR	2.154	HOURS OF OPERATION	807.1 HRS
		I2R TEMPERING ENERGY	20.7 KWH
		DEFROST HP ENERGY	4.9 KWH
		TOTAL DEFROST TIME	2.1 HRS
		NUMBER OF DEFROSTS	22.3

0*** ANNUAL ENERGY USE BREAKDOWN:

0-- DYNAMIC LOSS BREAKDOWN --

OFROSTING/DEFROSTING LOSSES -

DIRECT FROSTING/DEFROSTING ENERGY LOSS	12.9 KWH
INDIRECT CHANGE	

IN BACKUP HEAT REQUIREMENTS	-0.8 KWH
IN CYCLING LOSSES	2.7 KWH
IN PARASITICS	0.0 KWH

ANNUAL ENERGY LOSS DUE TO FROSTING/DEFROSTING	14.8 KWH
OCYCLING LOSSES -	
DIRECT CYCLING ENERGY LOSS	157.3 KWH
INDIRECT CHANGE	
IN PARASITICS	0.0 KWH

ANNUAL ENERGY LOSS DUE TO CYCLING	157.3 KWH
-----------------------------------	-----------

0-- USE AND LOSS SUMMARY --

OSTEADY-STATE ENERGY USE -

BASE TOTAL, EXCLUDING BACKUP HEAT AND PARASITICS	1820.1 KWH (86.5%)
BACKUP HEAT REQUIREMENTS	111.0 KWH (5.3%)
ON-TIME PARASITICS	0.0 KWH (0.0%)
OFF-TIME PARASITICS	0.0 KWH (0.0%)
ODYNAMIC LOSSES -	
FROSTING/DEFROSTING	14.8 KWH (0.7%)
CYCLING	157.3 KWH (7.5%)
-----	-----
TOTAL ENERGY USE FOR THE YEAR	2103.2 KWH (100.0%)

1

B.15 Dual-Speed Mode HVAC/Loads Data File Results (SOT=32°F)

INPUT SUMMARY:

ELECTRIC-DRIVEN HEAT PUMP

SAMPLE RUN OF A LENNOX TWO-SPEED WITH LOW-SPEED LOCKOUT IN HEATING

***** SUMMARY OF HEATING PERFORMANCE DATA:

LENNOX(2-SPEED) HP14 LEGEND II SERIES--HP14-261/411V W CP12-41V/E12Q3
(STEP CAPACITY MODULATION ALTERNATING TWO CAPACITY LEVELS
AT APPROPRIATE AMBIENTS)

----- HEATING MODE DATA FOR -----
----- MODULATION RATIO OF 0.50 -----

*** STEADY-STATE DATA:

PT	AMBIENT TEMPERATURE (F)	STEADY-STATE POWER (KWH)	PT	AMBIENT TEMPERATURE (F)	STEADY-STATE CAPACITY (KBTUH)
1	-15.00	.010	1	-15.00	0.00
2	5.00	.010	2	5.00	0.00
3	15.00	.010	3	15.00	0.00
4	25.00	1.140	4	25.00	14.12
5	35.00	1.220	5	35.00	17.76
6	45.00	1.310	6	45.00	21.40
7	50.00	1.350	7	50.00	23.20
8	55.00	1.400	8	55.00	25.10
9	60.00	1.440	9	60.00	26.80
10	65.00	1.480	10	65.00	28.70

*** CYCLING LOSS DATA:

CD = 0.220

*** FROST/DEFROST DATA:

ORNL TUBE & PLATE FIN, FROSTING/RECOVERY DATA USED

FROST INITIATION POINT = 37.00 DEG F
DEFROST TEMPERING HEAT = 10.00 KW

DEFROST COOLING CAPACITY GIVEN BY ORNL WAVY FIN DATA
DEFROST COOLING COP GIVEN BY ORNL WAVY FIN DATA

DEFROST LENGTH AND
TIME BETWEEN DEFROSTS GIVEN BY ORNL WAVY FIN DATA

*** ON-TIME PARASITIC DATA:

ON-TIME PARASITIC POWER IS 835.00 WATTS TIMES THE FRACTIONAL ON TIME.
AMOUNT OF ON-TIME PARASITICS ADDED TO S-S CAPACITY VALUES IS 0.00 WATTS
AMOUNT OF ON-TIME PARASITICS ADDED TO S-S COP VALUES IS 835.00 WATTS

----- HEATING MODE DATA FOR -----
----- MODULATION RATIO OF 1.00 -----

*** STEADY-STATE DATA:

PT	AMBIENT TEMPERATURE (F)	STEADY-STATE POWER (KWH)	PT	AMBIENT TEMPERATURE (F)	STEADY-STATE CAPACITY (KBTUH)
1	-15.00	1.490	1	-15.00	7.60
2	5.00	1.940	2	5.00	14.80
3	15.00	2.100	3	15.00	19.30
4	25.00	2.330	4	25.00	23.77
5	35.00	2.580	5	35.00	29.29
6	45.00	2.840	6	45.00	34.00
7	50.00	2.980	7	50.00	36.70
8	55.00	3.130	8	55.00	39.46
9	60.00	3.260	9	60.00	42.09
10	65.00	3.400	10	65.00	44.60

*** CYCLING LOSS DATA:

CD = 0.200

*** FROST/DEFROST DATA:

ORNL TUBE & PLATE FIN, FROSTING/RECOVERY DATA USED

FROST INITIATION POINT = 42.00 DEG F
DEFROST TEMPERING HEAT = 10.00 KW

DEFROST COOLING CAPACITY GIVEN BY ORNL WAVY FIN DATA
DEFROST COOLING COP GIVEN BY ORNL WAVY FIN DATA

DEFROST LENGTH AND
TIME BETWEEN DEFROSTS GIVEN BY ORNL WAVY FIN DATA

*** ON-TIME PARASITIC DATA:

ON-TIME PARASITIC POWER IS 835.00 WATTS TIMES THE FRACTIONAL ON TIME.
AMOUNT OF ON-TIME PARASITICS ADDED TO S-S CAPACITY VALUES IS 0.00 WATTS
AMOUNT OF ON-TIME PARASITICS ADDED TO S-S COP VALUES IS 835.00 WATTS

***** SUMMARY OF COOLING PERFORMANCE DATA:

LENNOX(2-SPEED) HP14 LEGEND II SERIES--HP14-261/411V W CP12-41V/E12Q3
(STEP CAPACITY MODULATION ALTERNATING TWO CAPACITY LEVELS
AT APPROPRIATE AMBIENTS)

----- COOLING MODE DATA FOR -----
----- MODULATION RATIO OF 0.50 -----

*** STEADY-STATE DATA:

PT	AMBIENT TEMPERATURE (F)	STEADY-STATE POWER (KWH)	PT	AMBIENT TEMPERATURE (F)	STEADY-STATE CAPACITY (KBTUH)
1	75.00	1.360	1	75.00	18.32
2	85.00	1.440	2	85.00	18.01
3	95.00	1.560	3	95.00	17.70
4	105.00	1.680	4	105.00	17.40

*** CYCLING LOSS DATA:

CD = 0.130

*** ON-TIME PARASITIC DATA:

ON-TIME PARASITIC POWER IS 835.00 WATTS TIMES THE FRACTIONAL ON TIME.
AMOUNT OF ON-TIME PARASITICS ADDED TO S-S CAPACITY VALUES IS 0.00 WATTS

AMOUNT OF ON-TIME PARASITICS ADDED TO S-S COP VALUES IS 835.00 WATTS

----- COOLING MODE DATA FOR -----
----- MODULATION RATIO OF 1.00 -----

*** STEADY-STATE DATA:

PT	AMBIENT TEMPERATURE (F)	STEADY-STATE POWER (KWH)	PT	AMBIENT TEMPERATURE (F)	STEADY-STATE CAPACITY (KBTUH)
1	75.00	3.170	1	75.00	28.53
2	85.00	3.340	2	85.00	27.52
3	95.00	3.500	3	95.00	26.50
4	105.00	3.660	4	105.00	25.49

*** CYCLING LOSS DATA:

CD = 0.130

*** ON-TIME PARASITIC DATA:

ON-TIME PARASITIC POWER IS 835.00 WATTS TIMES THE FRACTIONAL ON TIME.
AMOUNT OF ON-TIME PARASITICS ADDED TO S-S CAPACITY VALUES IS 0.00 WATTS
AMOUNT OF ON-TIME PARASITICS ADDED TO S-S COP VALUES IS 835.00 WATTS

***** MODE AND MODULATION INDEPENDENT HEAT PUMP DATA:

*** OFF-TIME PARASITIC DATA:

OFF-TIME PARASITIC POWER IS 0.00 WATTS TIMES THE FRACTIONAL OFF TIME.

*** UNIT SIZE SCALING:

THE INPUT CAPACITY, POWER, AND PARASITIC VALUES WERE NOT SCALED

***** HOUSE, WEATHER, AND LOADS INFORMATION:

167**2 RANCH, TECH HOUSE 3
THE HOUSE HAS 1800. SQUARE FEET OF FLAT ROOF AREA WITH
R-38. CEILING AND
R-19. WALLS

WEATHER FOR NOXVILLE, TN

WINTER INDOOR TEMPERATURE SETTING - DB = 70.00 F
SUMMER INDOOR TEMPERATURE SETTING - DB = 78.00 F
SUMMER INDOOR TEMPERATURE SETTING - WB = 67.00 F

99.0% DESIGN DAY TEMPERATURE--HEATING = 13.00 F
97.5% DESIGN DAY TEMPERATURE--COOLING = 92.00 F

DESIGN HEATING LOAD = 30.00 KBTU/HR
DESIGN COOLING LOAD = 22.00 KBTU/HR

COOLING SEASON SENSIBLE-TO-TOTAL COOLING LOAD RATIOS
BY AMBIENT TEMPERATURE BINS --

AMBIENT TEMP (F)	52.0	57.0	62.0	67.0	72.0	77.0	82.0	87.0	92.0	97.0
102.0										
S/T RATIO	1.000	0.984	0.929	0.847	0.831	0.840	0.868	0.835	0.831	0.826
0.800										

1PERFORMANCE CALCULATIONS:

SAMPLE RUN OF A LENNOX TWO-SPEED WITH LOW-SPEED LOCKOUT IN HEATING

LENNOX(2-SPEED) HP14 LEGEND II SERIES--HP14-261/411V W CP12-41V/E12Q3
167**2 RANCH, TECH HOUSE 3
NOXVILLE, TN

0***** HEATING SEASON CALCULATIONS:

(STEP CAPACITY MODULATION ALTERNATING TWO CAPACITY LEVELS
AT APPROPRIATE AMBIENTS)

MDPT		AVE	COP			CAP		% ON DEMAND	BACKUP ENERGY	ENERGY		
TEMP	HRS	LOAD	S-S	F/D	F/D/C	S-S	F/D	TIME	RATE	I2R	IN	OUT
(F)		(KBTUH)							(KW)	(KWH)	(KWH)	(KBTU)
-13.	2.	36.01	1.01	1.01	1.01	8.21	8.21	100.	12.38	16.3	21.0	72.0
-8.	2.	39.11	1.15	1.15	1.15	9.85	9.85	100.	12.50	17.1	22.2	78.2
-3.	3.	27.20	1.30	1.30	1.30	11.63	11.63	100.	12.62	13.7	21.5	81.6
2.	12.	23.13	1.46	1.46	1.46	13.57	13.57	100.	12.72	33.6	66.2	277.6
7.	3.	25.06	1.63	1.63	1.63	15.65	15.65	100.	12.81	8.3	16.7	75.2
12.	7.	22.01	1.81	1.81	1.81	17.89	17.89	100.	12.89	8.5	28.7	154.1
17.	19.	22.62	1.99	1.99	1.99	20.20	20.33	100.	13.00	12.7	69.7	429.7
22.	33.	21.71	2.13	2.11	2.09	22.43	22.43	97.	3.12	0.0	100.3	716.3
27.	61.	17.60	2.26	2.23	2.09	24.79	25.40	74.	3.34	0.0	150.6	1073.7
32.	143.	15.31	2.43	2.32	2.23	17.77	18.51	86.	2.34	0.0	287.9	2189.8
37.	136.	11.83	2.61	2.61	2.41	18.49	18.49	69.	2.07	0.0	195.8	1608.5
42.	142.	7.47	2.81	2.81	2.42	20.31	20.31	43.	2.12	0.0	128.4	1060.2
47.	165.	4.23	3.00	3.00	2.47	22.12	22.12	23.	2.16	0.0	82.9	697.5
52.	163.	2.92	3.18	3.18	2.57	23.95	23.95	15.	2.20	0.0	54.4	476.7
57.	141.	1.54	3.36	3.36	2.66	25.80	25.80	8.	2.25	0.0	23.9	217.0
62.	63.	1.12	3.52	3.52	2.78	27.54	27.54	5.	2.29	0.0	7.5	70.8
67.	59.	0.49	3.70	3.70	2.90	29.46	29.46	2.	2.33	0.0	2.9	29.0
72.	28.	0.11	3.88	3.88	3.03	31.36	31.36	0.	2.37	0.0	0.3	3.1

*** HEATING SEASON PERFORMANCE SUMMARY:

SEASONAL ENERGY INPUT	1280.8 KWH	BACKUP I2R ENERGY	110.2 KWH
SEASONAL ENERGY OUTPUT	9310.9 KBTU	PARASITIC ENERGY	0.0 KWH
SEASONAL PERFORMANCE FACTOR	2.130	HOURS OF OPERATION	481.5 HRS
		I2R TEMPERING ENERGY	26.5 KWH
		DEFROST HP ENERGY	4.6 KWH
		TOTAL DEFROST TIME	2.7 HRS
		NUMBER OF DEFROSTS	28.6

0*** SEASONAL ENERGY USE BREAKDOWN:

0-- DYNAMIC LOSS BREAKDOWN --

OFROSTING/DEFROSTING LOSSES -

DIRECT FROSTING/DEFROSTING ENERGY LOSS	16.6 KWH
INDIRECT CHANGE	
IN BACKUP HEAT REQUIREMENTS	-0.8 KWH
IN CYCLING LOSSES	3.4 KWH
IN PARASITICS	0.0 KWH

SEASONAL ENERGY LOSS DUE TO FROSTING/DEFROSTING	19.2 KWH
OCYCLING LOSSES -	
DIRECT CYCLING ENERGY LOSS	83.3 KWH
INDIRECT CHANGE	
IN PARASITICS	0.0 KWH

SEASONAL ENERGY LOSS DUE TO CYCLING 83.3 KWH

0-- USE AND LOSS SUMMARY --

0STEADY-STATE ENERGY USE -

BASE TOTAL, EXCLUDING BACKUP HEAT AND PARASITICS	1067.3 KWH (83.3%)
BACKUP HEAT REQUIREMENTS	111.0 KWH (8.7%)
ON-TIME PARASITICS	0.0 KWH (0.0%)
OFF-TIME PARASITICS	0.0 KWH (0.0%)

0DYNAMIC LOSSES -

FROSTING/DEFROSTING	19.2 KWH (1.5%)
CYCLING	83.3 KWH (6.5%)

TOTAL ENERGY USE FOR THE SEASON 1280.8 KWH (100.0%)

1PERFORMANCE CALCULATIONS:

SAMPLE RUN OF A LENNOX TWO-SPEED WITH LOW-SPEED LOCKOUT IN HEATING

LENNOX(2-SPEED) HP14 LEGEND II SERIES--HP14-261/411V W CP12-41V/E12Q3
167**2 RANCH, TECH HOUSE 3
NOXVILLE, TN

0*** COOLING SEASON CALCULATIONS:

(STEP CAPACITY MODULATION WITH ONLY ONE CAPACITY LEVEL
USED AT EACH AMBIENT)

MDPT	AVE	COP		CAP		% ON	DEMAND	BACKUP	ENERGY	ENERGY		
TEMP	HRS	LOAD	S-S	F/D	F/D/C	S-S	F/D	TIME	RATE	I2R	IN	OUT
(F)		(KBTUH)							(KW)	(KWH)	(KWH)	(KBTU)
57.	35.	0.59	2.70	2.70	2.36	18.88	18.88	4.	2.05	0.0	2.5	20.5
62.	61.	1.95	2.62	2.62	2.32	18.72	18.72	12.	2.09	0.0	15.0	118.7
67.	222.	3.50	2.55	2.55	2.28	18.57	18.57	21.	2.13	0.0	99.7	776.9
72.	223.	5.87	2.49	2.49	2.26	18.41	18.41	35.	2.17	0.0	169.3	1308.9
77.	143.	8.50	2.42	2.42	2.25	18.26	18.26	50.	2.21	0.0	158.0	1216.1
82.	118.	9.66	2.36	2.36	2.22	18.10	18.10	57.	2.25	0.0	150.7	1140.3
87.	92.	11.89	2.29	2.29	2.19	17.95	17.95	69.	2.30	0.0	146.3	1093.9
92.	35.	12.85	2.21	2.21	2.13	17.79	17.79	75.	2.35	0.0	61.8	449.8
97.	1.	14.61	2.14	2.14	2.09	17.64	17.64	85.	2.42	0.0	2.0	14.6
102.	1.	15.03	2.07	2.07	2.03	17.49	17.49	88.	2.48	0.0	2.2	15.0

*** COOLING SEASON PERFORMANCE SUMMARY:

0SEASONAL ENERGY INPUT	807.6 KWH	BACKUP I2R ENERGY	0.0 KWH
SEASONAL ENERGY OUTPUT	6154.7 KBTU	PARASITIC ENERGY	0.0 KWH
SEASONAL PERFORMANCE FACTOR	2.233	HOURS OF OPERATION	363.5 HRS

0*** SEASONAL ENERGY USE BREAKDOWN:

0-- DYNAMIC LOSS BREAKDOWN --

OCYCLING LOSSES -

DIRECT CYCLING ENERGY LOSS	56.4 KWH
INDIRECT CHANGE IN PARASITICS	0.0 KWH

SEASONAL ENERGY LOSS DUE TO CYCLING 56.4 KWH

0-- USE AND LOSS SUMMARY --

OSTEADY-STATE ENERGY USE -

BASE TOTAL, EXCLUDING BACKUP HEAT AND PARASITICS	751.1 KWH (93.0%)
BACKUP HEAT REQUIREMENTS	0.0 KWH (0.0%)
ON-TIME PARASITICS	0.0 KWH (0.0%)
OFF-TIME PARASITICS	0.0 KWH (0.0%)

ODYNAMIC LOSSES -

FROSTING/DEFROSTING	0.0 KWH (0.0%)
CYCLING	56.4 KWH (7.0%)

TOTAL ENERGY USE FOR THE SEASON 807.6 KWH (100.0%)

1PERFORMANCE CALCULATIONS:

SAMPLE RUN OF A LENNOX TWO-SPEED WITH LOW-SPEED LOCKOUT IN HEATING

LENNOX(2-SPEED) HP14 LEGEND II SERIES--HP14-261/411V W CP12-41V/E12Q3
167**2 RANCH, TECH HOUSE 3
NOXVILLE, TN

*** ANNUAL PERFORMANCE SUMMARY:

0ANNUAL ENERGY INPUT	2088.4 KWH	BACKUP I2R ENERGY	110.2 KWH
ANNUAL ENERGY OUTPUT	15465.6 KBTU	PARASITIC ENERGY	0.0 KWH
ANNUAL PERFORMANCE FACTOR	2.170	HOURS OF OPERATION	845.1 HRS
		I2R TEMPERING ENERGY	26.5 KWH
		DEFROST HP ENERGY	4.6 KWH
		TOTAL DEFROST TIME	2.7 HRS
		NUMBER OF DEFROSTS	28.6

0*** ANNUAL ENERGY USE BREAKDOWN:

0-- DYNAMIC LOSS BREAKDOWN --

OFROSTING/DEFROSTING LOSSES -

DIRECT FROSTING/DEFROSTING ENERGY LOSS	16.6 KWH
INDIRECT CHANGE IN BACKUP HEAT REQUIREMENTS	-0.8 KWH
IN CYCLING LOSSES	3.4 KWH
IN PARASITICS	0.0 KWH

ANNUAL ENERGY LOSS DUE TO FROSTING/DEFROSTING	19.2 KWH
OCYCLING LOSSES -	
DIRECT CYCLING ENERGY LOSS	139.8 KWH
INDIRECT CHANGE	
IN PARASITICS	0.0 KWH
-----	-----
ANNUAL ENERGY LOSS DUE TO CYCLING	139.8 KWH
0-- USE AND LOSS SUMMARY --	
OSTEADY-STATE ENERGY USE -	
BASE TOTAL, EXCLUDING BACKUP HEAT AND PARASITICS	1818.4 KWH (87.1%)
BACKUP HEAT REQUIREMENTS	111.0 KWH (5.3%)
ON-TIME PARASITICS	0.0 KWH (0.0%)
OFF-TIME PARASITICS	0.0 KWH (0.0%)
ODYNAMIC LOSSES -	
FROSTING/DEFROSTING	19.2 KWH (0.9%)
CYCLING	139.8 KWH (6.7%)
-----	-----
TOTAL ENERGY USE FOR THE YEAR	2088.4 KWH (100.0%)

B.16 Single-Speed Mode HVAC/Loads Data File Results for Load
Conditions Identical to Dual-Speed Loads

INPUT SUMMARY:

ELECTRIC-DRIVEN HEAT PUMP

SAMPLE RUN OF A LENNOX 2-SPEED WITH HIGH SPEED COMPRESSOR OPERATION ONLY

***** SUMMARY OF HEATING PERFORMANCE DATA:

LENNOX(2-SPEED) HP14 LEGEND II SERIES--HP14-261/411V W CP12-41V/E12Q3
(NO CAPACITY MODULATION)

*** STEADY-STATE DATA:

AMBIENT			STEADY-STATE		
PT	TEMPERATURE		POWER	PT	TEMPERATURE
	(F)		(KWH)		(F)
1	-15.00		1.490	1	-15.00
2	5.00		1.940	2	5.00
3	15.00		2.100	3	15.00
4	25.00		2.330	4	25.00
5	35.00		2.580	5	35.00
6	45.00		2.840	6	45.00
7	50.00		2.980	7	50.00
8	55.00		3.130	8	55.00
9	60.00		3.260	9	60.00
10	65.00		3.400	10	65.00

AMBIENT			STEADY-STATE		
PT	TEMPERATURE		CAPACITY	PT	TEMPERATURE
	(F)		(KBTUH)		(F)
1	-15.00		7.60	1	-15.00
2	5.00		14.80	2	5.00
3	15.00		19.30	3	15.00
4	25.00		23.77	4	25.00
5	35.00		29.29	5	35.00
6	45.00		34.00	6	45.00
7	50.00		36.70	7	50.00
8	55.00		39.46	8	55.00
9	60.00		42.09	9	60.00
10	65.00		44.60	10	65.00

*** CYCLING LOSS DATA:

CD = 0.200

*** FROST/DEFROST DATA:

ORNL TUBE & PLATE FIN, FROSTING/RECOVERY DATA USED

FROST INITIATION POINT = 42.00 DEG F

DEFROST TEMPERING HEAT = 10.00 KW

DEFROST COOLING CAPACITY GIVEN BY ORNL WAVY FIN DATA

DEFROST COOLING COP GIVEN BY ORNL WAVY FIN DATA

DEFROST LENGTH AND

TIME BETWEEN DEFROSTS GIVEN BY ORNL WAVY FIN DATA

*** ON-TIME PARASITIC DATA:

ON-TIME PARASITIC POWER IS 835.00 WATTS TIMES THE FRACTIONAL ON TIME.
 AMOUNT OF ON-TIME PARASITICS ADDED TO S-S CAPACITY VALUES IS 0.00 WATTS
 AMOUNT OF ON-TIME PARASITICS ADDED TO S-S COP VALUES IS 835.00 WATTS

***** SUMMARY OF COOLING PERFORMANCE DATA:

LENNOX(2-SPEED) HP14 LEGEND II SERIES--HP14-261/411V W CP12-41V/E12Q3
 (NO CAPACITY MODULATION)

*** STEADY-STATE DATA:

PT	AMBIENT TEMPERATURE (F)	STEADY-STATE POWER (KWH)	PT	AMBIENT TEMPERATURE (F)	STEADY-STATE CAPACITY (KBTUH)
1	75.00	3.170	1	75.00	28.53
2	85.00	3.340	2	85.00	27.52
3	95.00	3.500	3	95.00	26.50
4	105.00	3.660	4	105.00	25.49

*** CYCLING LOSS DATA:

CD = 0.130

*** ON-TIME PARASITIC DATA:

ON-TIME PARASITIC POWER IS 835.00 WATTS TIMES THE FRACTIONAL ON TIME.
 AMOUNT OF ON-TIME PARASITICS ADDED TO S-S CAPACITY VALUES IS 0.00 WATTS
 AMOUNT OF ON-TIME PARASITICS ADDED TO S-S COP VALUES IS 835.00 WATTS

***** MODE AND MODULATION INDEPENDENT HEAT PUMP DATA:

*** OFF-TIME PARASITIC DATA:

OFF-TIME PARASITIC POWER IS 0.00 WATTS TIMES THE FRACTIONAL OFF TIME.

*** UNIT SIZE SCALING:

THE INPUT CAPACITY, POWER, AND PARASITIC VALUES WERE NOT SCALED

***** HOUSE, WEATHER, AND LOADS INFORMATION:

167**2 RANCH, TECH HOUSE 3
THE HOUSE HAS 1800. SQUARE FEET OF FLAT ROOF AREA WITH
R-38. CEILING AND
R-19. WALLS

WEATHER FOR NOXVILLE, TN

WINTER INDOOR TEMPERATURE SETTING - DB = 70.00 F
SUMMER INDOOR TEMPERATURE SETTING - DB = 78.00 F
SUMMER INDOOR TEMPERATURE SETTING - WB = 67.00 F

99.0% DESIGN DAY TEMPERATURE--HEATING = 13.00 F
97.5% DESIGN DAY TEMPERATURE--COOLING = 92.00 F

DESIGN HEATING LOAD = 30.00 KBTU/HR
DESIGN COOLING LOAD = 22.00 KBTU/HR

COOLING SEASON SENSIBLE-TO-TOTAL COOLING LOAD RATIOS
BY AMBIENT TEMPERATURE BINS --

AMBIENT TEMP (F)	52.0	57.0	62.0	67.0	72.0	77.0	82.0	87.0	92.0	97.0
102.0										
S/T RATIO	1.000	0.984	0.929	0.847	0.831	0.840	0.868	0.835	0.831	0.826
0.800										

1PERFORMANCE CALCULATIONS:

SAMPLE RUN OF A LENNOX 2-SPEED WITH HIGH SPEED COMPRESSOR OPERATION ONLY

LENNOX(2-SPEED) HP14 LEGEND II SERIES--HP14-261/411V W CP12-41V/E12Q3
167**2 RANCH, TECH HOUSE 3
NOXVILLE, TN

0*** HEATING SEASON CALCULATIONS:
(NO CAPACITY MODULATION)

MDPT		AVE	COP			CAP		% ON	DEMAND	BACKUP	ENERGY	ENERGY
TEMP	HRS	LOAD	S-S	F/D	F/D/C	S-S	F/D	TIME	RATE	I2R	IN	OUT
(F)		(KBTUH)							(KW)	(KWH)	(KWH)	(KBTU)
-13.	2.	36.01	1.01	1.01	1.01	8.21	8.21	100.	12.38	16.3	21.0	72.0
-8.	2.	39.11	1.15	1.15	1.15	9.85	9.85	100.	12.50	17.1	22.2	78.2
-3.	3.	27.20	1.30	1.30	1.30	11.63	11.63	100.	12.62	13.7	21.5	81.6
2.	12.	23.13	1.46	1.46	1.46	13.57	13.57	100.	12.72	33.6	66.2	277.6
7.	3.	25.06	1.63	1.63	1.63	15.65	15.65	100.	12.81	8.3	16.7	75.2
12.	7.	22.01	1.81	1.81	1.81	17.89	17.89	100.	12.89	8.5	28.7	154.1
17.	19.	22.62	1.99	1.99	1.99	20.20	20.33	100.	13.00	12.7	69.7	429.7
22.	33.	21.71	2.13	2.11	2.09	22.43	22.43	97.	3.12	0.0	100.3	716.3
27.	61.	17.60	2.26	2.23	2.09	24.79	25.40	74.	3.34	0.0	150.6	1073.7
32.	143.	15.31	2.42	2.33	2.12	27.52	28.38	59.	3.56	0.0	302.8	2189.8
37.	136.	11.83	2.56	2.46	2.15	30.30	31.66	43.	3.77	0.0	219.2	1608.5
42.	142.	7.47	2.66	2.66	2.25	32.67	32.67	27.	3.60	0.0	138.0	1060.2
47.	165.	4.23	2.75	2.75	2.27	35.05	35.05	15.	3.73	0.0	90.1	697.5
52.	163.	2.92	2.86	2.86	2.33	37.80	37.80	9.	3.87	0.0	59.9	476.7
57.	141.	1.54	2.95	2.95	2.39	40.53	40.53	5.	4.02	0.0	26.6	217.0
62.	63.	1.12	3.04	3.04	2.45	43.11	43.11	3.	4.15	0.0	8.5	70.8
67.	59.	0.49	3.11	3.11	2.50	45.60	45.60	1.	4.29	0.0	3.4	29.0
72.	28.	0.11	3.18	3.18	2.55	48.11	48.11	0.	4.43	0.0	0.4	3.1

*** HEATING SEASON PERFORMANCE SUMMARY:

SEASONAL ENERGY INPUT	1345.6 KWH	BACKUP I2R ENERGY	110.2 KWH
SEASONAL ENERGY OUTPUT	9310.9 KBTU	PARASITIC ENERGY	0.0 KWH
SEASONAL PERFORMANCE FACTOR	2.027	HOURS OF OPERATION	355.8 HRS
		I2R TEMPERING ENERGY	34.4 KWH
		DEFROST HP ENERGY	8.2 KWH
		TOTAL DEFROST TIME	3.4 HRS
		NUMBER OF DEFROSTS	34.6

0*** SEASONAL ENERGY USE BREAKDOWN:

0-- DYNAMIC LOSS BREAKDOWN --

0FROSTING/DEFROSTING LOSSES -

DIRECT FROSTING/DEFROSTING ENERGY LOSS	20.6 KWH
INDIRECT CHANGE	
IN BACKUP HEAT REQUIREMENTS	-0.8 KWH
IN CYCLING LOSSES	4.6 KWH
IN PARASITICS	0.0 KWH

SEASONAL ENERGY LOSS DUE TO FROSTING/DEFROSTING	24.4 KWH
OCYCLING LOSSES -	
DIRECT CYCLING ENERGY LOSS	116.3 KWH
INDIRECT CHANGE	
IN PARASITICS	0.0 KWH

SEASONAL ENERGY LOSS DUE TO CYCLING	116.3 KWH
O-- USE AND LOSS SUMMARY --	
OSTEADY-STATE ENERGY USE -	
BASE TOTAL, EXCLUDING BACKUP HEAT AND PARASITICS	1093.9 KWH (81.3%)
BACKUP HEAT REQUIREMENTS	111.0 KWH (8.2%)
ON-TIME PARASITICS	0.0 KWH (0.0%)
OFF-TIME PARASITICS	0.0 KWH (0.0%)
ODYNAMIC LOSSES -	
FROSTING/DEFROSTING	24.4 KWH (1.8%)
CYCLING	116.3 KWH (8.6%)

TOTAL ENERGY USE FOR THE SEASON	1345.6 KWH (100.0%)

1PERFORMANCE CALCULATIONS:

SAMPLE RUN OF A LENNOX 2-SPEED WITH HIGH SPEED COMPRESSOR OPERATION ONLY

LENNOX(2-SPEED) HP14 LEGEND II SERIES--HP14-261/411V W CP12-41V/E12Q3

167**2 RANCH, TECH HOUSE 3

NOXVILLE, TN

O*** COOLING SEASON CALCULATIONS:

(NO CAPACITY MODULATION)

MDPT	AVE	COP				CAP		% ON DEMAND		BACKUP	ENERGY	ENERGY
TEMP	HRS	LOAD	S-S	F/D	F/D/C	S-S	F/D	TIME	RATE	I2R	IN	OUT
(F)		(KBTUH)							(KW)	(KWH)	(KWH)	(KBTU)
57.	35.	0.59	2.40	2.40	2.10	30.35	30.35	2.	3.70	0.0	2.9	20.5
62.	61.	1.95	2.31	2.31	2.03	29.84	29.84	7.	3.78	0.0	17.1	118.7
67.	222.	3.50	2.22	2.22	1.97	29.34	29.34	13.	3.87	0.0	115.7	776.9
72.	223.	5.87	2.14	2.14	1.92	28.83	28.83	23.	3.95	0.0	200.2	1308.9
77.	143.	8.50	2.05	2.05	1.87	28.33	28.33	33.	4.04	0.0	190.8	1216.1
82.	118.	9.66	1.98	1.98	1.81	27.82	27.82	38.	4.13	0.0	184.7	1140.3
87.	92.	11.89	1.90	1.90	1.76	27.32	27.32	47.	4.21	0.0	181.9	1093.9
92.	35.	12.85	1.83	1.83	1.71	26.81	26.81	51.	4.29	0.0	77.2	449.8
97.	1.	14.61	1.76	1.76	1.66	26.30	26.30	59.	4.37	0.0	2.6	14.6
102.	1.	15.03	1.70	1.70	1.61	25.79	25.79	62.	4.45	0.0	2.7	15.0

*** COOLING SEASON PERFORMANCE SUMMARY:

SEASONAL ENERGY INPUT	975.8 KWH	BACKUP I2R ENERGY	0.0 KWH
SEASONAL ENERGY OUTPUT	6154.7 KBTU	PARASITIC ENERGY	0.0 KWH

SEASONAL PERFORMANCE FACTOR 1.848

HOURS OF OPERATION 240.3 HRS

0*** SEASONAL ENERGY USE BREAKDOWN:

0-- DYNAMIC LOSS BREAKDOWN --

0CYCLING LOSSES -

DIRECT CYCLING ENERGY LOSS	88.3 KWH
INDIRECT CHANGE	
IN PARASITICS	0.0 KWH

SEASONAL ENERGY LOSS DUE TO CYCLING

88.3 KWH

0-- USE AND LOSS SUMMARY --

0STEADY-STATE ENERGY USE -

BASE TOTAL, EXCLUDING BACKUP HEAT AND PARASITICS	887.4 KWH (90.9%)
BACKUP HEAT REQUIREMENTS	0.0 KWH (0.0%)
ON-TIME PARASITICS	0.0 KWH (0.0%)
OFF-TIME PARASITICS	0.0 KWH (0.0%)

0DYNAMIC LOSSES -

FROSTING/DEFROSTING	0.0 KWH (0.0%)
CYCLING	88.3 KWH (9.1%)

TOTAL ENERGY USE FOR THE SEASON

975.8 KWH (100.0%)

1PERFORMANCE CALCULATIONS:

SAMPLE RUN OF A LENNOX 2-SPEED WITH HIGH SPEED COMPRESSOR OPERATION ONLY

LENNOX(2-SPEED) HP14 LEGEND II SERIES--HP14-261/411V W CP12-41V/E12Q3

167***2 RANCH, TECH HOUSE 3

NOXVILLE, TN

*** ANNUAL PERFORMANCE SUMMARY:

0ANNUAL ENERGY INPUT	2321.4 KWH	BACKUP I2R ENERGY	110.2 KWH
ANNUAL ENERGY OUTPUT	15465.6 KBTU	PARASITIC ENERGY	0.0 KWH
ANNUAL PERFORMANCE FACTOR	1.952	HOURS OF OPERATION	596.0 HRS

I2R TEMPERING ENERGY	34.4 KWH
DEFROST HP ENERGY	8.2 KWH
TOTAL DEFROST TIME	3.4 HRS
NUMBER OF DEFROSTS	34.6

0*** ANNUAL ENERGY USE BREAKDOWN:

0-- DYNAMIC LOSS BREAKDOWN --

0FROSTING/DEFROSTING LOSSES -

DIRECT FROSTING/DEFROSTING ENERGY LOSS	20.6 KWH
--	----------

INDIRECT CHANGE	
IN BACKUP HEAT REQUIREMENTS	-0.8 KWH
IN CYCLING LOSSES	4.6 KWH
IN PARASITICS	0.0 KWH

ANNUAL ENERGY LOSS DUE TO FROSTING/DEFROSTING	24.4 KWH
OCYCLING LOSSES -	
DIRECT CYCLING ENERGY LOSS	204.6 KWH
INDIRECT CHANGE	
IN PARASITICS	0.0 KWH

ANNUAL ENERGY LOSS DUE TO CYCLING	204.6 KWH
0-- USE AND LOSS SUMMARY --	
OSTEADY-STATE ENERGY USE -	
BASE TOTAL, EXCLUDING BACKUP HEAT AND PARASITICS	1981.4 KWH (85.4%)
BACKUP HEAT REQUIREMENTS	111.0 KWH (4.8%)
ON-TIME PARASITICS	0.0 KWH (0.0%)
OFF-TIME PARASITICS	0.0 KWH (0.0%)
ODYNAMIC LOSSES -	
FROSTING/DEFROSTING	24.4 KWH (1.1%)
CYCLING	204.6 KWH (8.8%)

TOTAL ENERGY USE FOR THE YEAR	2321.4 KWH (100.0%)

APPENDIX C

C.1 Uncertainty Analysis

Based on the results of a previous data accuracy study of the instrumentation used at the TECH facility (7) which estimated the uncertainty in measurement along with additional uncertainty introduced by occasional DAS outages and integrator malfunctions, it is felt that the seasonal energy input was accurate to -1.0 to +1.0% and -2.0 to +2.0% while the seasonal energy output was accurate to -2.0 to +2.0% and -5.0 to +5.0%. Using an uncertainty analysis method outlined in Reference 11 and applying this analysis to the following equation:

$$C = O/I$$

where

C = COP

O = seasonal energy output total

I = seasonal energy input total

gives

$$w_c = ((\partial C / \partial O * w_o)^2 + (\partial C / \partial I * w_I)^2)^{1/2}$$

Applying the range of uncertainties believed to best estimate the values involved at the TECH facility as previously mentioned, the range of COP values obtained are shown in Table C.1. From the results given in this table it can be concluded that the uncertainties obtained in the performance values for both the single and dual-speed modes is the same order of magnitude as the difference in the performance values obtained from the field analysis.

Table C.1 Overall Results of Uncertainty Analysis

Mode Description	HSPF	CSPF
Single-speed mode nominal value	2.109	2.092
$w_o = 2.0\%$, $w_I = 1.0\%$	2.062-2.156	2.045-2.139
$w_o = 2.0\%$, $w_I = 2.0\%$	2.049-2.169	2.033-2.151
$w_o = 5.0\%$, $w_I = 2.0\%$	1.995-2.223	1.979-2.205
Dual-speed mode nominal value	2.172	2.267
$w_o = 2.0\%$, $w_I = 1.0\%$	2.123-2.221	2.216-2.318
$w_o = 2.0\%$, $w_I = 2.0\%$	2.111-2.233	2.203-2.331
$w_o = 5.0\%$, $w_I = 2.0\%$	2.055-2.289	2.145-2.389

VITA

John Randall Carr was born in Knoxville, Tennessee on November 3, 1958. He attended Cedar Bluff Elementary School and was graduated from Farragut High School in June 1977. The following September he entered the University of Tennessee and in June 1981 he received a Bachelor of Science in Mechanical Engineering. He then accepted a position with NAP Consumer Electronics in Knoxville where he worked until October 1984. After this he worked for Process Systems Incorporated in Charlotte, North Carolina until July 1985.

In September 1985 he entered the Mechanical Engineering graduate program at the University of Tennessee in Knoxville. He received a Master of Science in Mechanical Engineering in August 1987.

The author is a member of the American Society of Mechanical Engineers.